Containment Building:

Architecture Between *the* City and Advanced Nuclear Reactors

by

Lisa M. Pauli

B.S. Interior Design
University of Texas at Austin, 2004

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARCHITECTURE
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ABSTRACT:

Since the inception of nuclear energy research, the element thorium (Th) has been considered the superior fuel for nuclear reactions because of its potency, safety, abundance and reduced waste. Cold War agendas broke from the logic of efficient energy production to establish a nationwide network of reactors designed to enrich uranium fuel for a nuclear arsenal. Contemporary dilemmas of global warming, increasing fuel prices, carbon emissions, and anti-proliferation movements have brought the discussion of clean, safe nuclear power to the forefront of American energy policy; it is no longer tolerable or sustainable to rely on a uranium (U) nuclear network. The architectural typology of nuclear energy has not been addressed in America for 35 years and is one that belies the promise of clean energy's progress through technology and public intervention. Containment Building is an architectural response to nuclear technological advancement that challenges historical separation between nuclear power and the public. It is a self-sustained, thorium-powered nuclear plant sited in and powering New York City. It is a nuclear campus that programatically and urbanistically engages the public and contains radio isotope labs, a nuclear medicine and imaging facility, a food irradiation center, a wellness hotel and spa, an electric taxi charging station, and a plug-in park along the Hudson River waterfront.

Thesis Supervisor: J. Meejin Yoon
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To Liz and Steve Pauli

Biographical Note

Lisa Pauli is the daughter of Stephen and Elizabeth Pauli. She has two siblings, Angela Schuchardt and Joe Pauli. She was raised in Elkhart, IN until the age of 15 when she and her family relocated to Houston, TX. Throughout high school she was awarded for her accomplishments in the arts at state and national levels. She graduated from Clear Lake High School in May, 2000. Lisa attended the University of Texas at Austin from August, 2000 through May, 2004 when she attained her Bachelor of Science in Interior Design. Her interest in interior design stemmed from years in the fine arts and a love for geometry. She was awarded the Angelo Donghia Foundation scholarship, the winning result of a national interior design competition and graduated with honors. In the fall of 2004, Lisa moved to New York City to pursue her career in interior architecture and design. During her three years in New York, her time was split between two firms: Cleanroom Inc, and Maya Lin Studio. Her professional experience grew exponentially as she was worked on furniture, lighing, lounge design, inflatable environments, a ground up Manhattan building, museum and residential designs, as well as major earthworks, artworks, and installations. Submerged in the field of architecture, she was eager to expand her professional capabilities and academic pursuits. In the fall of 2007 she relocated to Boston and began her studies at MIT. MIT presented her with numerous challenges and opportunities. Her work proved successful and respected as she was awarded the merit-based tuition scholarship in 2008, 2009, and 2010. She was also granted the Louis G. Seigle Award, managed by MIT's Office of the Dean of Graduate Students, for entrepreneurial activities. In addition to her academic work, she was selected to create the 2010 Department of Architecture Faculty Exhibit, the 2010 NAAB Student Exhibit, and worked as a researcher for a collaborative project between Japan's Sekisui House and MIT Department of Architecture and Planning. She was recognized for Outstanding Service to the Department of Architecture by Yung Ho Chang in 2010. Lisa held Teaching Assistantships for Ute Meta Bauer's Contemporary Curatorial Practice and for Nick Gelpi's undergraduate design studio. Throughout her education, she also participated in a number of international workshops, collaborations, and design-builds in Japan, Taiwan, Italy, and Cambodia.

Acknowledgments

First and foremost, I would like to thank my parents, Liz and Steve Pauli, for their unending love and support, without which I would never have had the means to pursue the things I love. In life, they have always done everything to encourage me to pursue goals, and opportunities they may not have been fortunate to have had. For this and more, I am forever grateful.

To Marc, my love, partner, adviser, and best friend, who stood beside me throughout my education and beyond: answering late night phone calls, making emergency drives across New England, and flying across the country to catch the final hours of my thesis. Your heart knows no bounds. Thank you for helping me in the wee hours to bring this project into fruition, and for taking time for critiques and reviews. You have seen my highs and lows and I am so happy that our years apart are over.

There are countless people who made my academic experience at MIT and this project what it has blossomed into. I would like to thank the faculty who have challenged me during my studies at MIT and made for an amazing academic experience, namely Nader Tehrani, Ana Miljacki, Andrew Scott, and Alexander D'Hooghe. The impact of all of your teachings is evidenced in this project. Thanks to the administration for keeping the greater organization of my degree, awards, and titles in order, namely Anne Simunovic, Jack Valelli, Cynthia Stewart and Rebecca Chamberlain. Thanks again to my thesis committee: Meejin Yoon, Mark Jarzombek, and Gediminas Urbonas, for helping me steer this project in the right direction, for posing challenging questions of the project and for meeting on nights and holidays. Angela Schuchardt, my sister, thank you for the care packages, letters, and phone calls! You're a wonderful sister and mom and always dropped me a line when I needed it most. Kellyn, my niece, your photos hung in my studio always brought me a great smile. Joe Pauli, you are hilarious and are going to make it big some day. Sarah Hirschman, my best friend, you are amazing and talented, thank you for the late night studio dance parties, I look forward to our future collaborations. I want to especially thank the people who helped finalize my thesis in the last week: Marc Cucco, Ryan Maliszewski, Masoud Akbarzadeh, and Daniela Covarrubias . Ryan, you were more than gracious and am ready to lend you a hand when your thesis comes.

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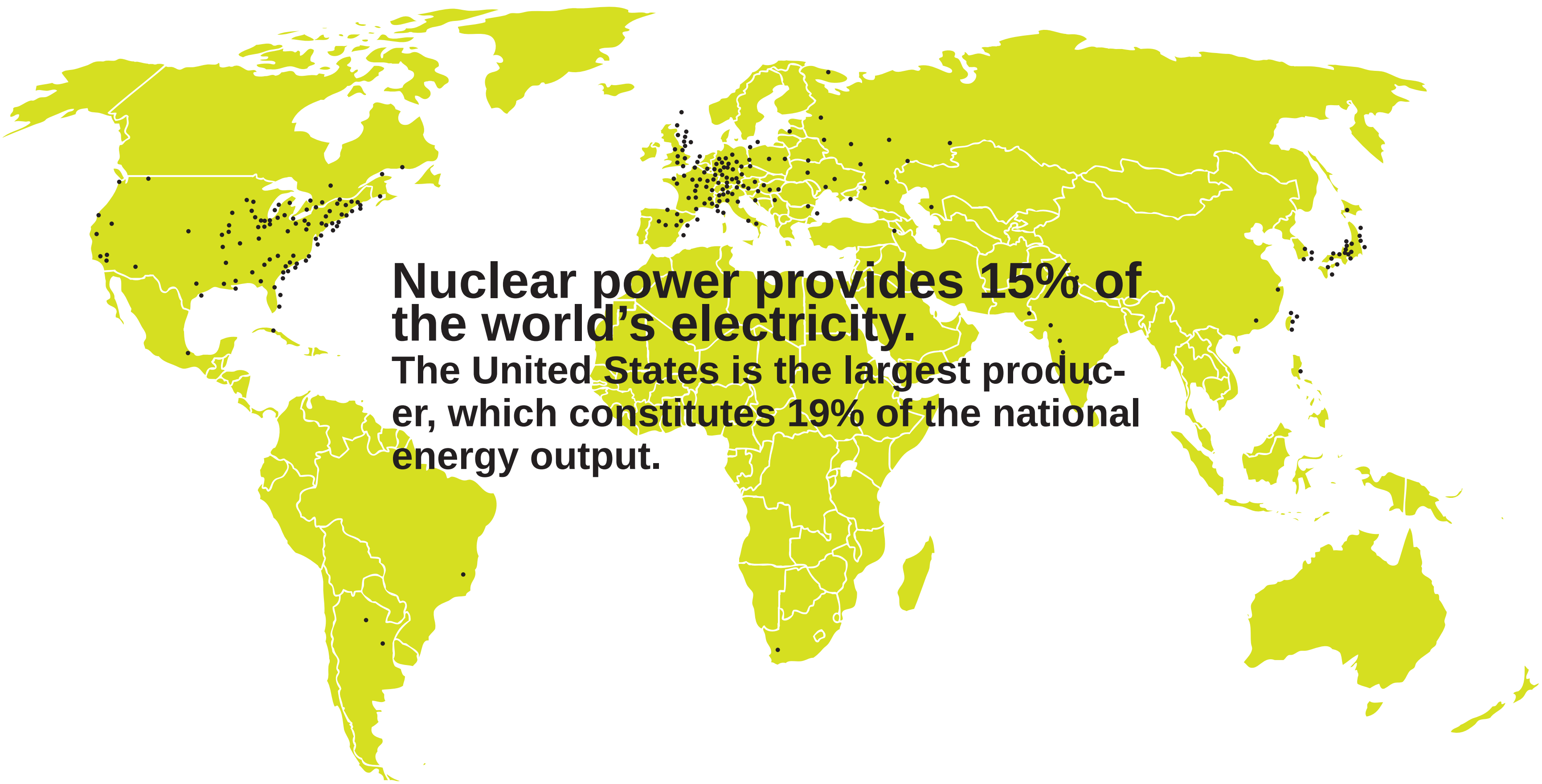
Preface

I will begin by saying that I am not, in any way, an authority on nuclear power or nuclear technologies. Containment Building is an architectural response to one year of research and studies that reveal historical and developmental nuclear technologies as I have found them. I have spoken to nuclear scientists at NASA and MIT, all who had varying degrees of responses to my proposal. The intent is not to approach the question of advanced nuclear technologies as a scientist, but as a designer with questions, ideas, and challenges to developing nuclear technologies and how they could potentially affect architecture and people. As you will see in this text, I have taken both models of existing nuclear implementations in France as well as ideological models of utopian, electric cities are precedent; I found that somewhere in between is a means to proposing a forward-thinking (if not futuristic) architecture grounded on real, working models of nuclear plants, cities, and military applications.

The idea for Containment Building was born from an article in *Wired Magazine* written by Richard Martin on December 21, 2009 entitled, “Uranium Is So Last Century — Enter Thorium, the New Green Nuke”. I was in Tokyo for an academic research position and had brought a few magazines that I had been meaning to read on the trip. *Wired* is striking to me, not as a primary resource for science and technology, but as a collection of one to five page sound bites that often inspire me to gather more information on the subjects elsewhere. Of course, their compelling yet straightforward graphics do well to intrigue me as both designer and academic. The article highlighted the non-proliferating possibilities of using thorium as opposed to uranium to fuel nuclear power plants and highlighted discussions with NASA engineer and scientist, Kirk Sorensen. The convincing graphics displayed scalar, economic, and output comparisons between a traditional uranium-powered light water reactor plant and a liquid fluoride thorium reactor (LFTR). The text intrigued me; I had never heard of thorium before, much less alternative forms of nuclear power. I was not sure what exactly this had to do with architecture, but advanced technologies that challenge the scale, safety, and proximity of traditionally hazardous and controversial structures to the public seemed intriguing.



Nuclear power provides 15% of the world’s electricity.

The United States is the largest producer, which constitutes 19% of the national energy output.

image by author

Introduction:
1. A Brief History of Nuclear Energy

Timeline:

Nuclear power currently supplies 15% of the world's electricity. The United States leads with highest ratio of nuclear energy produced: 19% of energy we consume (Nuclear Power). The commercial nuclear power industry skyrocketed after 1954 when the world's first commercial nuclear power plant was created after nearly half a century of internationally competitive research in pursuit for superior nuclear warfare. The nuclear arms race began with Manhattan project in 1942 as the Soviet Union became aware of America's nuclear developments and began developing an atomic bomb of their own(U.S. Department of Energy,2). The race spurred national investment in uranium, the only element, aside from pure Plutonium, which when enriched and subject to nuclear fission (therefore producing plutonium), could be used to arm nuclear warheads. Here began a nationwide infrastructural network supporting the production and testing of uranium-fueled reactors called the nuclear weapons complex(U.S. Department of Energy, 2). While nuclear weapon testing ensued, nuclear physicists researched ways to harness energy for power distribution. Researchers named the more abundant element, thorium to be the most efficient energy producer, requiring less heat, needing zero enrichment, resulting in less waste, and overall safer than the uranium-fueled reactors(Chirkov, 650). However, with the Department of Defense's investment in infrastructure for uranium enrichment and harvesting, nuclear energy was limited to only one fuel option.

As early as 1975 geologists predicted that if nuclear energy production continued at the same exponential rate, by 2010 the world's then ample supply of uranium would be severely depressed(Chirkov, 647). Today, the adverse affects of uranium nuclear facilities have scarred America. With the decommissioning of nuclear weapons complex hubs, shortages of uranium, nuclear plant failures scares, and over 300,000 barrels of plutonium-contaminated radioactive waste buried throughout the country, the United States is in need of a major nuclear revision(U.S. Department of Energy, 2). We are amidst a new race: one for cleaner nuclear energy production. Nuclear development, research, and international testing labs are at the forefront of the news and worldwide concerns for greener energy, smarter systems, and carbon reductions bring thorium back into the spotlight. Yet even with the world's second largest deposit of thorium, the United States is reluctant to anchor implementation and sends researchers elsewhere to experiment thorium-based nuclear power("Thorium", 2). Scientists are utilizing technologies developed at Oak Ridge National Laboratories (TN) such as thorium rods to retrofit existing power plants and new Molten Salt reactors that run solely on thorium in the United Kingdom, India, France, and Russia("Thorium," 5-7). Millions of dollars are being spent to ship thorium abroad and to reclaim foreign enriched uranium and nuclear byproducts from hybrid reactors. The United States' involvement in international moves to advance (and police) the nuclear industry are abundant, yet the government has done little to sever its own attachment to nuclear warfare. In fact, the United States has not financially supported any homeland nuclear power stations since the early 1970's, until recently.

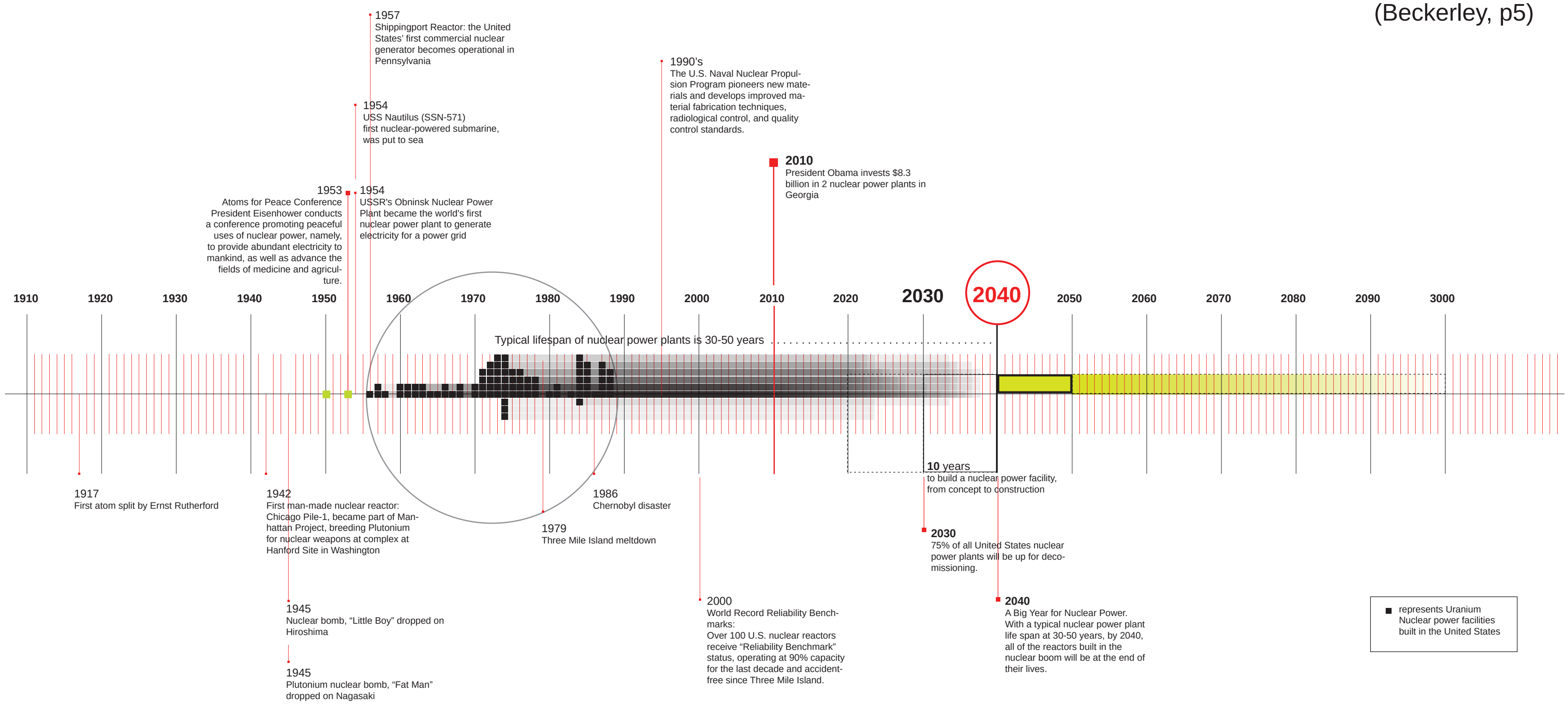
On February, 16, 2010, President Obama announced a new plan to invest $8.3 billion in the research and construction of two nuclear power facilities in Georgia(Wald). The first federal nuclear investment in over 30 years, the plan is aimed at spurring a nuclear resurgence and to create thousands of jobs. The revival of the existing American industry is key in advancing future nuclear technologies; after nearly 100 under construction reactors were abandoned between the 1970's and 80's, the first step in advancing nuclear technology is to reacquaint America with nuclear power(Wald). We must foreground nuclear research and education in America.

Situating a New Nuclear Facility Amidst a Historical Past

The advent of nuclear power launched a skyrocketing industry facilities across America, highlighting the 1970's as nuclear power's most prolific decade. After nuclear disasters like Three Mile Island and the meltdown at Chernobyl, waning sociopolitical support brought the nuclear plant-building industry to a halt. Thirty-five years later, America is once again investing in the industry, but what does this

"…the United States pledges before you – and therefore before the world – its determination to help solve the fearful atomic dilemma- to devote its entire heart and mind to find the way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life."

President Dwight D. Eisenhower
Address before the General Assembly of the United Nations,
December 8, 1953.
(Beckerley, p5)



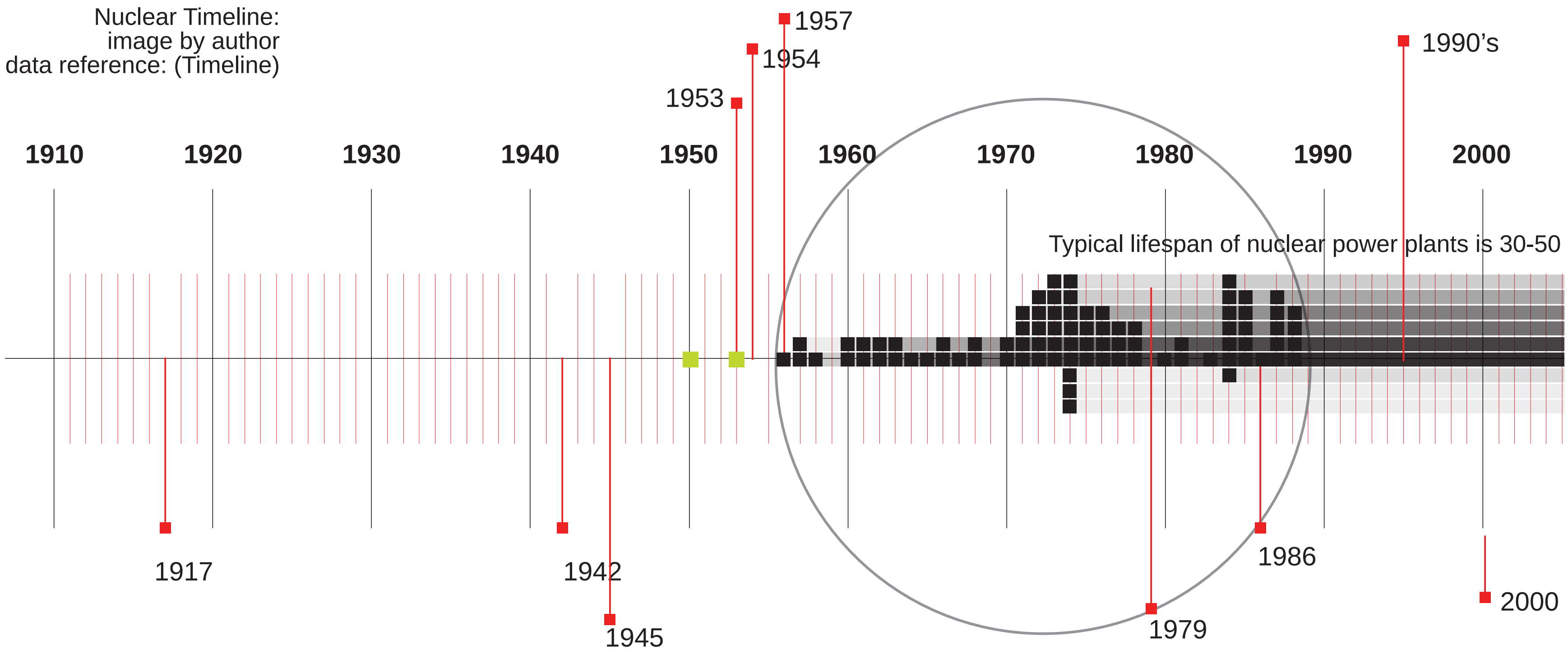
Nuclear Timeline
note: drawing as designed by author, see pp 18-19 for details

for new nuclear facilities? Already, the existing nuclear plants are approaching the end of their lifespan, as most of the facilities built from 1950 to the late 1980's are projected to last approximately 40-50 years(Openshaw)[1]. Many of the existing facilities have already undergone decommissioning, leaving a strong infrastructural network with depleting nodes. Researchers are developing "fourth generation" reactors that focus on waste reduction, increased safety, and alternative fuels, among them: the liquid fluoride thorium reactor (LFTR). The development history of the past shows that it takes approximately ten years, from concept to facility completion, to build a nuclear facility(Openshaw,15). With President Obama''s current initiatives, the earliest starting point of this project would be around 2020. However, since this new nuclear facility will rely on alternative fuel sources, I project the implementation of this project between 2030 and 2040. Hypothetically, this allows a decade to establish a thorium extraction industry. By examining when power plants were built in comparison to their projected lifespan, one can surmise that by 2030, every existing nuclear facility in the United States will have reached the end of its projected lifespan. Whether or not these facilities continue to operate, a majority of them will certainly be decommissioned, leaving an underutilized network for the transport of fuel, waste, and electricity. The need for a new nuclear facility is more apparent than ever and it is upon this network and situational urgency that Containment Building is grounded.

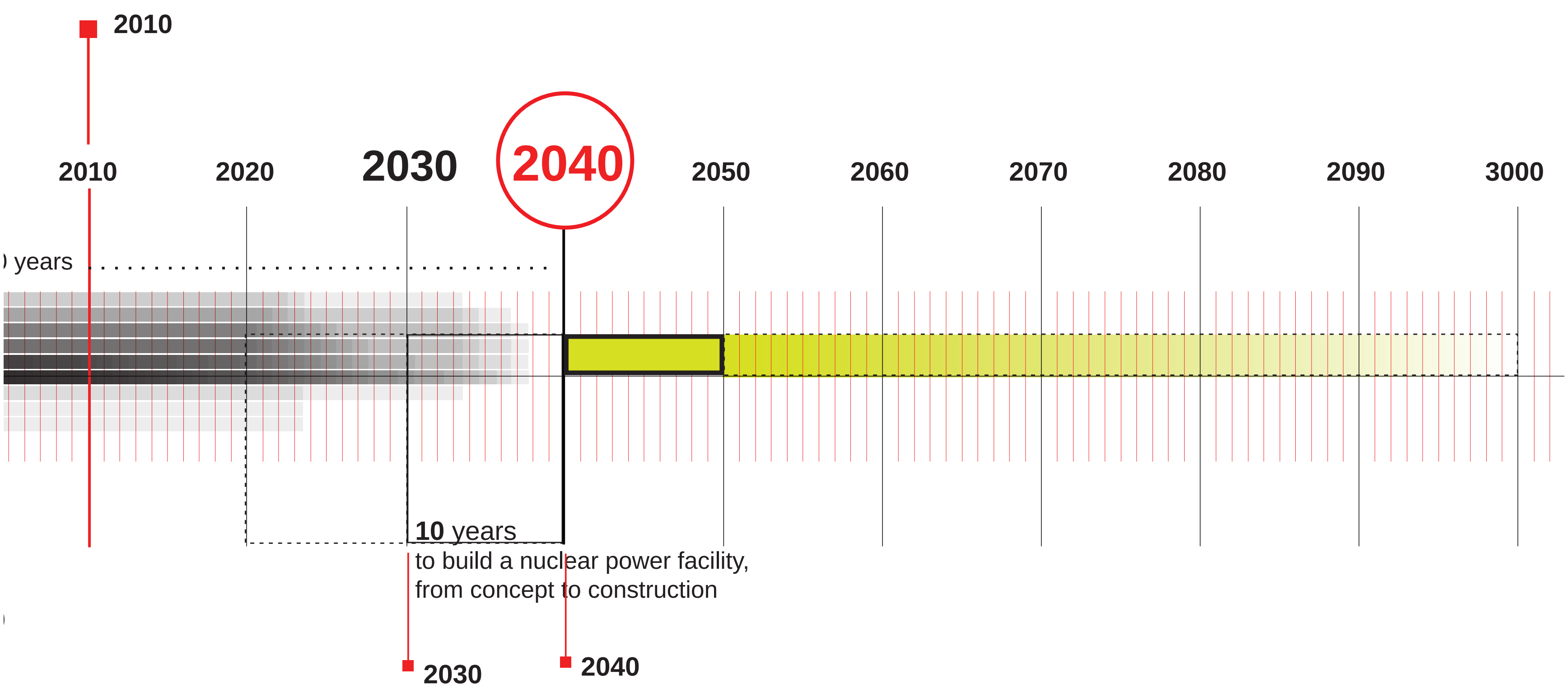
Decommissioning + Prospecting:
According to a convention set by International Atomic Energy Agency, it takes approximately 100 years to completely dismantle an existing nuclear power station(Barrie, 17). During the first ten years the removal of nuclear fuel, uncontaminated buildings, and plant takes place. It takes the next 85 years for all remaining radioactive material, packaged into storage, to decay and five more years to dismantle reactors and send all remaining contaminated materials to a waste repository(Barrie, 17). While radioactive containment is underway, a vast area of land is available for alternative use, but prospects for the site will be both limited and contentious. Decommissioning is a very lengthy, expensive, and most notably wasteful process, but material waste volume is only a fragment of the concern. Infrastructure for dispersing energy has a much longer lifespan than nuclear power facilities and can be fixed on a need by need basis(Barrie, 17). The connection to the electric grid is a powerful argument for siting new, cleaner energy generating facilities on these sites. Fourth generation nuclear reactors like the LFTR are only 2,000-3,000 sq ft, 1% the area of existing typical nuclear power station which occupy 200,000 – 300,000 sq ft of land(Martin). The small footprint offers two advantages: 1.) an abundance of land on every existing nuclear reactor site and 2.) an opportunity for LFTRs to be placed discreetly amidst the American landscape.

By 2030, every existing nuclear facility in the United States will have reached the end of its projected lifespan, leaving an underutilized network for the transport of fuel, waste, and electricity.

1. The lifespan of a typical nuclear power plant is approximately 30-50 years(Openshaw,15). The end of it's days are not due to the structure itself, but the reactor components have a limited run before the radiation breaks them down. Following the reactor closure, it must be contained and secured for a number of years before being disassembled(Openshaw, 15).



Timeline: (Timeline)
1917
First atom split by Ernst Rutherford
1942
First man-made nuclear reactor:
Chicago Pile-1, became part of Manhattan Project, breeding Plutonium for nuclear weapons at complex at Hanford Site in Washington
1945
Nuclear bomb, "Little Boy" dropped on Hiroshima
1945
Plutonium nuclear bomb, "Fat Man" dropped on Nagasaki
1953
Atoms for Peace Conference
President Eisenhower conducts a conference promoting peaceful uses of nuclear power, namely, to provide abundant electricity to mankind, as well as advance the fields of medicine and agriculture.
1954
USSR's Obninsk Nuclear Power Plant became the world's first nuclear power plant to generate electricity for a power grid
1954
USS Nautilus (SSN-571)
first nuclear-powered submarine, was put to sea
1957
Shippingport Reactor: the United States' first commercial nuclear generator becomes operational in Pennsylvania
1979
Three Mile Island meltdown
1986
Chernobyl disaster
1990's



The U.S. Naval Nuclear Propulsion Program pioneers new materials and develops improved material fabrication techniques, radiological control, and quality control standards.

2000

World Record Reliability Benchmarks: Over 100 U.S. nuclear reactors receive “Reliability Benchmark” status, operating at 90% capacity for the last decade and accident-free since Three Mile Island.

2010

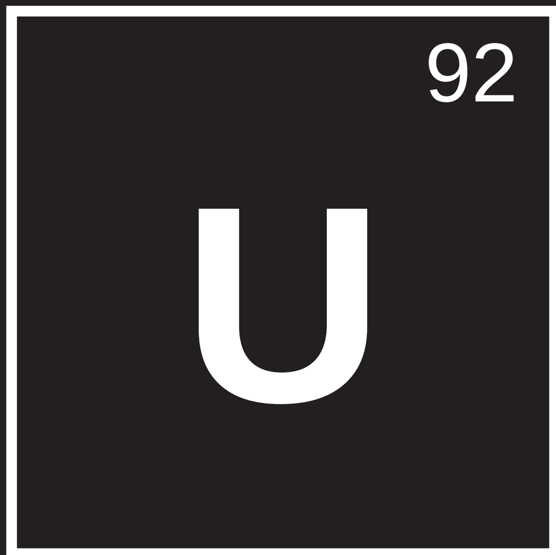
President Obama invests $8.3 billion in 2 nuclear power plants in Georgia

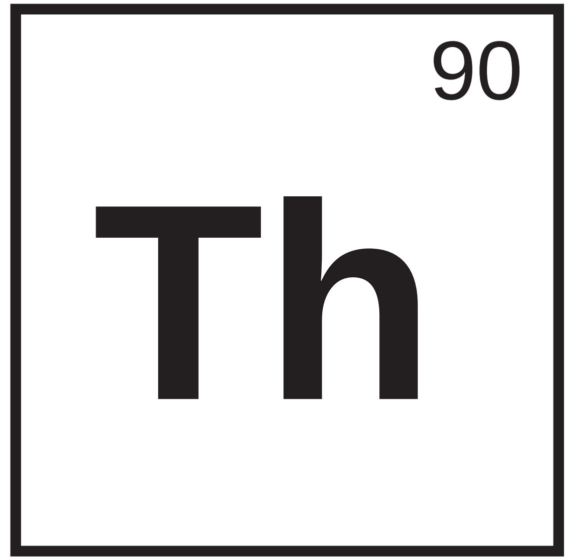
2030

75% of all United States nuclear power plants will be up for decomissioning.

2040

A Big Year for Nuclear Power.
With a typical nuclear power plant life span at 30-50 years, by 2040, all of the reactors built in the nuclear boom will be at the end of their lives.





Dominant Technology Faces an Alternative

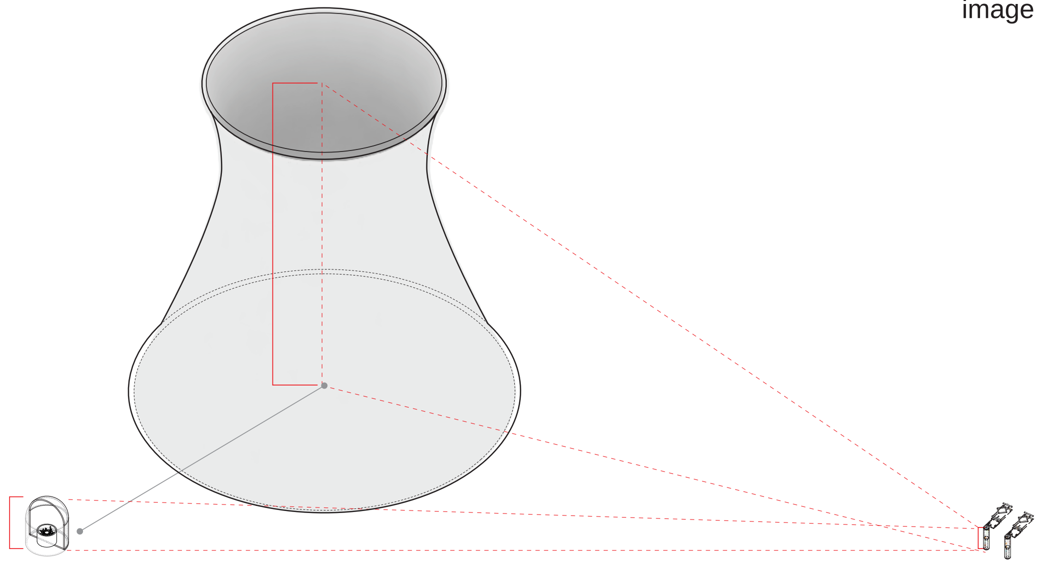
Nuclear power is the most viable form of
Nuclear power is the most viable form of
energy production. The rising price of fossil fuels, egregious carbon emissions of fuel-burning plants, and the high-cost, low-yield of passive energy systems today make nuclear power more critical than ever. Even so, existing nuclear technologies no longer suit contemporary conditions; anti-nuclear weapon agendas, the depletion of uranium, and the adverse association the American public has with antiquated nuclear technologies undermine uranium infrastructures. To open the eyes of the American public to nuclear power, a revolutionary, sustainable, non proliferating nuclear generation technology must be in place.

The future of American nuclear power will reap the benefits of American soil. Home to the world's second largest reserve of naturally occurring thorium, the United States is an ideal candidate for the revolutionary nuclear reactor., the LFTR. With a self-regulating coolant, low fuel input, and minimal building footprint, the Liquid Fluoride Thorium Reactor, seeks a new architectural identity, one that severs ties to past nuclear industry (LFTR) (Martin). Unlike the LWRs, the LFTR is not a symbol of wartime progress, but of safer, cleaner energy advancement. As an infrastructure without contemporary precedent, it must break the associations of past industry. Containment Building, America's new nuclear power plant, is a project of symbolism, expansion, and permanence. The architecture manifest must convey these characteristics and redefine clean energy generation in America. It is time for America to concentrate efforts locally and set an anti-arms, progressive energy example for the rest of the world.

Future technology

As we venture into the next few decades, generation II reactors will have come and gone. Generation III and IV reactors will dot the landscape, utilizing hyper-efficient fuel in safe, and compact containment structures. The unobtrusive structures will be associated with power of plenty. The abundance of clean, carbon-free nuclear energy resources will transform the way people and industry consume electricity. The compact form of the generation IV thorium nuclear reactor will promote the utmost of versatility in application. Its relatively small components make national mass production a cost effective response to antiquated, massive, customized generation units(Walters). The mass produced units will power facilities and communities of countless configurations of electricity demands and terrain variations. From sub-terrain facilities for particularly sensitive above ground conditions to submersive reactors and every topography in between, the generation IV reactors will supply electricity locally to mining towns and operations, industrial ports, technology hubs, suburban communities, and dense urban centers. The new power suppliers can be infinitely coupled to accommodate greater demands or used independently for more

image by author



1954-1988

Uranium-Fueled
Light Water Reactor
and Cooling Tower

2010

LFTR (Liquid Flouride
Thorium Reactor)
Gas -cooled w/ turbines
(No cooling tower)

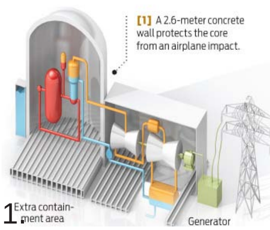
remote locations. The reliance on gas or sodium cooling removes the limitation of water-edge nuclear industry and further expands the possible sites for nuclear power generation. With zero carbon emissions and minimal waste, nuclear power will be conceived as something as close as your backyard.

In the 35 years since the last nuclear power plant was built in America, nuclear scientists have advanced reactor technology and proposed smaller, safer units.

This thesis nods to the various forms of reactors and supporting infrastructure outlined below and uses their existence and progress as precedent for technologies implemented in the future. Containment Building employs the LFTR not as an end, but as a means to approach architectural form between advanced nuclear reactors and the city. The following are reactors in progress that will make appearances in the near nuclear future.

Future Technology: Core Contenders
Models of Future Nuclear Reactors

The following are reactors in progress that will make appearances in the near nuclear future. The dimensions, fuel requirements, and output power were used to determine the scale and quantity of reactors that would be needed to power New York City.



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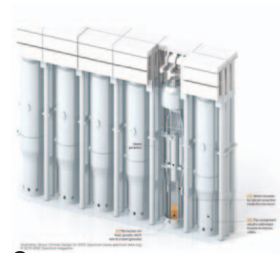
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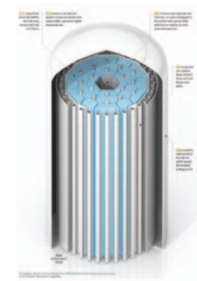
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1. EPR: Evolutionary Power Reactor (world's larges pressurized-water reactor

Type: Pressurized-water reactor
Power: Thermal, 4500 MW; electric, 1650 MW
Fuel:The reactor can use 5 percent enriched uranium oxide clad in fuel rods similar to those of conventional PWRs. It can also use fuel with up to 50 percent mixed uranium plutonium oxide.
Refueling: Every 24 months
Coolant: Water
Moderator: Water
Waste: Spent fuel, consisting of leftover uranium 235 and other highly radioactive waste.
Anticipated Implementation Date: Currently being built
Number of reactors needed to power New York City's 5 boroughs: 5

2. Westinghouse AP1000

Type: Pressurized-water reactor
Power: 3415 MW (thermal) 1117MW electric
Fuel: Enriched uranium clad in fuel assemblies similar to those in ordinary PWR's
Refueling: Every 18-24 months
Coolant: Water
Moderator: Water
Waste: Spent fuel, consisting of leftover uranium 235 and other highly radioactive waste, similar to standard PWR waste
Anticipated Implementation Date: U.S. construction to begin in 2016
Number of reactors needed to power New York City's 5 boroughs: 8

3. NuScale

Type: Light-water reactor
Power: Thermal, 160 MW; electric, 45 MW for one reactor module. A full-scale plant would have 12 to 24 modules, or an electric power capacity of 540 to 1080 MW.
Fuel: Nearly 5 percent enriched uranium in 1.8-meter-long fuel assemblies similar to those used today in standard light-water reactors
Refueling: Every 24 months
Coolant: Water
Moderator: Water
Waste: Spent fuel, consisting of leftover uranium 235 and other highly radioactive waste, similar to standard PWR waste.
Anticipated Implementation Date: 2018
Number of reactors needed to power New York City's 5 boroughs: 177 (or approximately 8 locations with 20 modules)

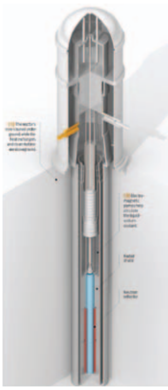
4. Hyperion Power Module

Type: Liquid-metal-cooled reactor
Power: Thermal, 70 MW; electric, 25 MW
Fuel: Stainless steel fuel pins confine solid-ceramic uranium nitride pellets. The fuel is enriched to just under 20 percent. (Typical PWR fuel is 3 to 5 percent. The Nuclear Non-Proliferation Treaty defines 20 percent enrichment as the lower limit for "special nuclear material," the level at which it is considered "weapons usable.")
Refueling: None. Entire unit is replaced every 8 to 10 years
Coolant: Liquid lead bismuth (liquid-metal-cooled reactors are usually sodium cooled)
Moderator: No moderator (it's a fast reactor)
Waste: Hyperion claims the HPM works as a disposable reactor: Instead of frequently replacing spent uranium with fresh fuel, refueling in this case means replacing the entire 20-metric-ton core with a brand new one. And Hyperion says it will take care of the used one.
Anticipated Implementation Date: 2015
Number of reactors needed to power New York City's 5 boroughs: 320

5. Toshiba 4S (Super, Safe, Small, and Simple)

Type: Liquid-sodium-cooled fast reactor
Power: Thermal, 30 MW; electric, 10 MW
Fuel: Uranium enriched to about 19.9 percent (just below the 20 percent weapons-usable threshold); the uranium is mixed with zirconium and clad in steel.
Refueling: The reactor is sealed and never

Illustrations by Brian Christie Design for IEEE Spectrum, © 2010, IEEE Spectrum Magazine



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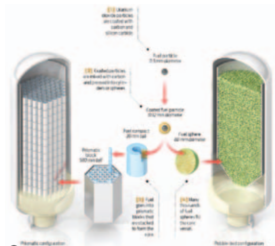

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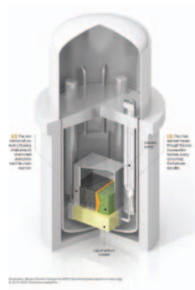


7.

refueled. When its fuel is exhausted after 30 years, the entire reactor core would be returned to the manufacturer for disposal, and another one could take its place.
Coolant: Liquid sodium
Moderator: No moderator (it's a fast reactor)
Waste: Spent fuel remains sealed in the core.
Anticipated Implementation Date: 2012-2017
Number of reactors needed to power New York City's 5 boroughs: 800

6. Next Generation Nuclear Power Plant

Type: High-temperature gas-cooled reactor
Power: Thermal, 250 to 600 MW; electric, 112 to 270 MW
Fuel: Microscopic particles of uranium dioxide coated with carbon and silicon carbide. These spheres, known as tristructural isotropic, or TRISO, particles, are then mixed with lots of graphite and pressed into one of two possible geometries: spheres the size of tennis balls (the pebble-bed design) or sticks the size of a piece of chalk that are inserted into hexagonal graphite blocks (the prismatic design).
Refueling: The spent fuel is continuously replaced without shutting down the reactor. In the pebble-bed type, TRISO balls are removed from the bottom to have their fission levels measured, and new balls are added to the top. In the prismatic reactor, thousands of hexagonal blocks are stacked and their TRISO fuel sticks replaced periodically.
Coolant: Helium
Moderator: Graphite
Waste: The spent fuel consists of balls (in the pebble-bed reactor) and sticks (in the prismatic reactor) containing leftover uranium that didn't undergo fission and other radioactive material; the waste would be stored in metal casks on-site.
Anticipated Implementation Date: 2011-2020
Number of reactors needed to power New York City's 5 boroughs: 30

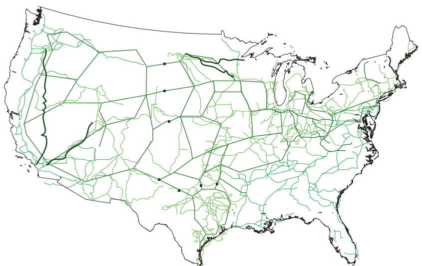
7. TerraPower TP-1

Type: Traveling-wave reactor
Power: Thermal, 900 to 1250 MW; electric, 350 to 500 MW. Designed as a modular reactor that can be combined into larger gigawatt-scale plants
Fuel: The main fuel is depleted uranium, which can be found as uranium hexafluoride, a by-product of the uranium enrichment that is a part of current fuel production. (The reactor can also use spent fuel from light-water reactors.) The uranium 238 is transformed into uranium metal-alloy fuel and placed into rods that will form the core. The core needs an "igniter" consisting of enriched uranium (10 to 12 percent of fissile uranium 235); the igniter represents a relatively low percentage of the core's weight.
Refueling: The reactor takes 40 to 50 years to consume fuel; no refueling is necessary during this period, but shuffling fuel rods to improve the burn-up rate might be required.
Coolant: Liquid sodium, which flows along the length of the fuel rods. Boron carbide control rods are placed within the current position of the wave, at locations where they can control power and reactivity.
Moderator: No moderator (it's a fast reactor)
Waste: Leftover uranium fuel, excess plutonium, and other high-level radioactive waste. Waste can remain in place after reactor is decommissioned.
Anticipated Implementation Date: 2020
Number of reactors needed to power New York City's 5 boroughs: 16

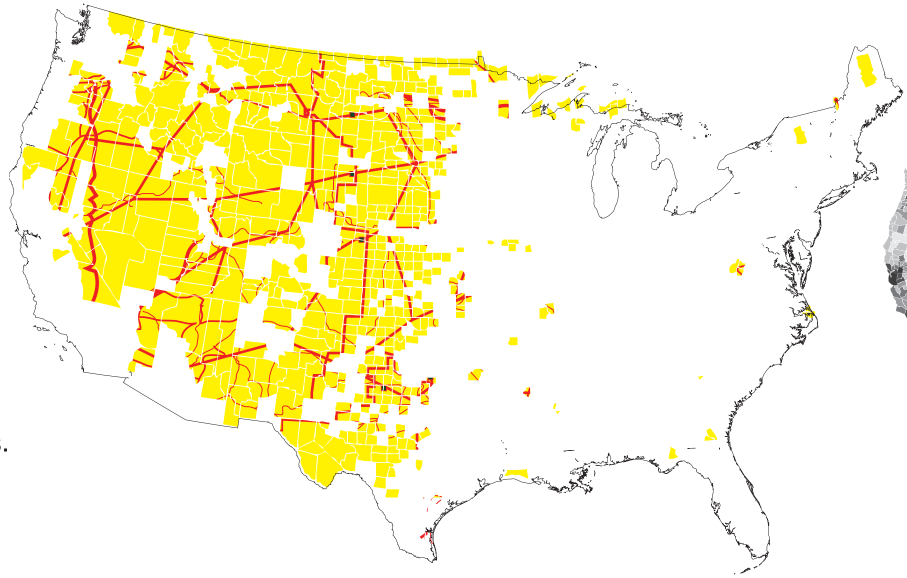
Data Source:
Adee, Sally and Erico Guizzo. "Nuclear Reactor Renaissance
Nuclear reactor design is poised for a desperately needed revival. Here are seven contenders." IEEE Spectrum Magazine: August, 2010
http://spectrum.ieee.org/energy/nuclear/nuclear-reactor-renaissance/0

Major power distribution lines extend opportunistically over vacant land

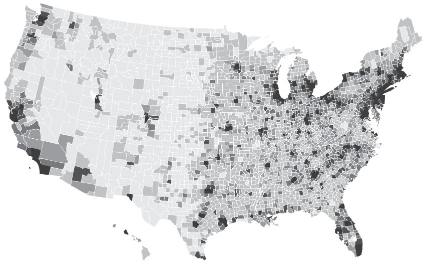
images by author
image source: see ref: NPR



United States transmission lines.



Overlay of U.S. lowest population density areas with high voltage transmission lines.



United States population map.

National Implications:

Reducing the scale of nuclear power plants will have national implications. The reactors will be fabricated in massive production lines in controlled factories. Shipping the components of the nuclear power plant to the site by train, ship, or highway, a network of power plant supply chains will emerge across the States. The compact reactors will be placed in city centers and around industries of high energy demand. By locating the power plants adjacent to the consumers, wasteful infrastructures that stretch across vacant, unpopulated land will gradually be eliminated. Cities and industries alike will become independent of far-off electric infrastructures. Additionally, by localizing power production, less transformers and substations will be needed to relentlessly boost power up and step power down to stretch across long distances, conserving energy and materials.

Critique of the U.S. Electric Grid:
Eliminating the Slack

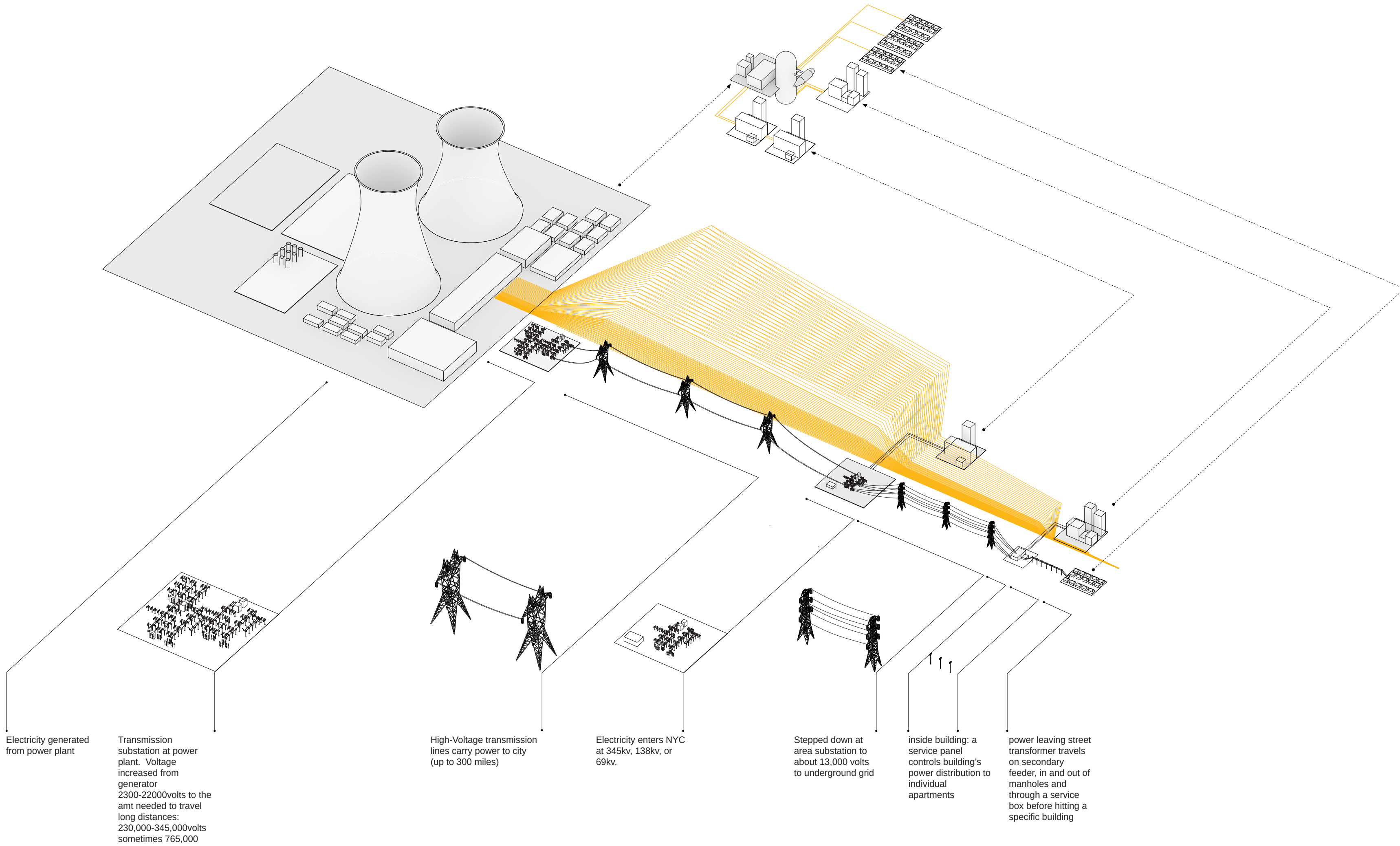
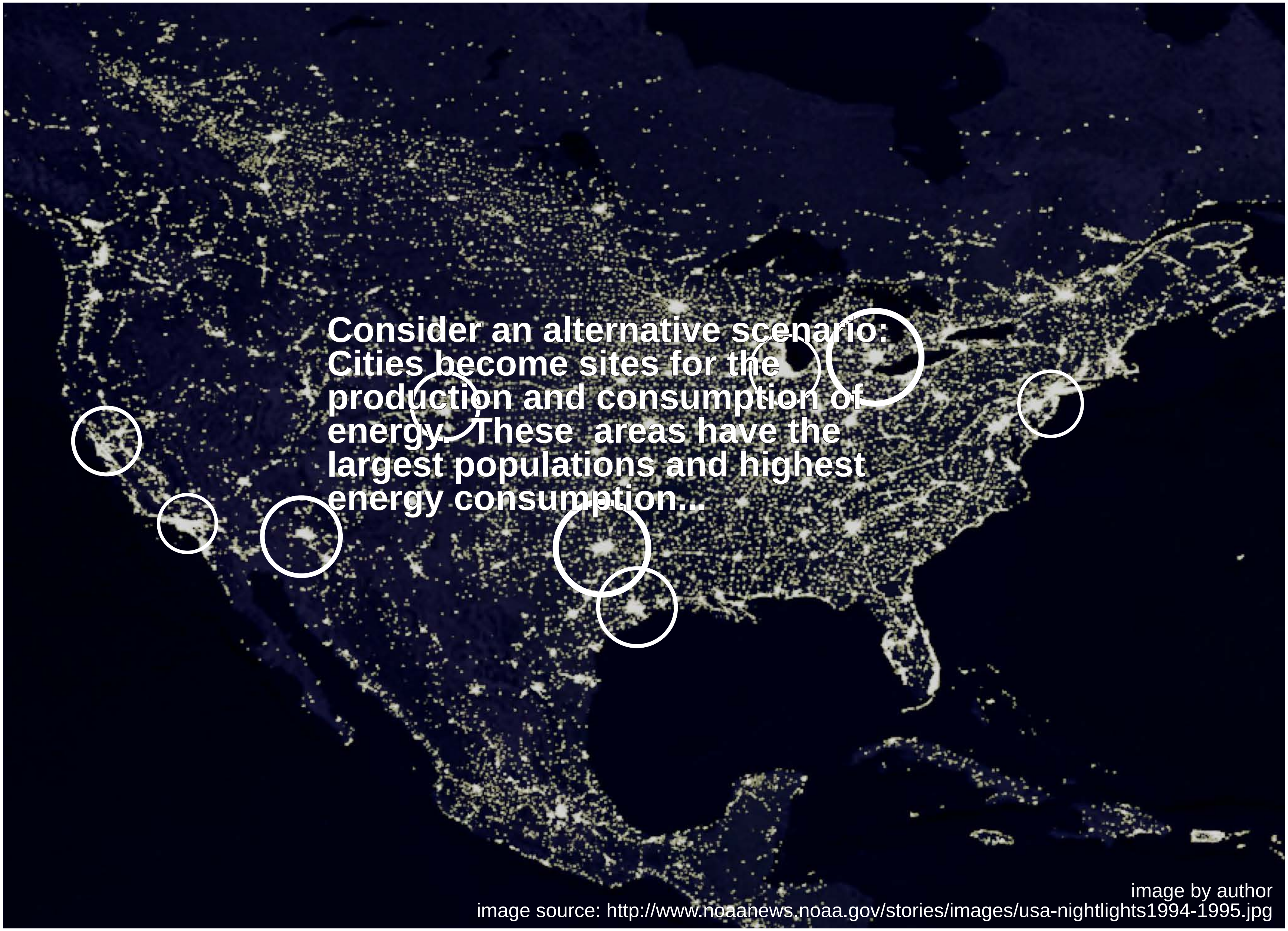


image by author
information source: see ref:Ascher


Consider an alternative scenario:
Cities become sites for the production and consumption of energy. These areas have the largest populations and highest energy consumption...
image by author
image source: http://www.noaanews.noaa.gov/stories/images/usa-nightlights1994-1995.jpg

2. An Argument for LFTRs in The City

Thesis Question:
What opportunities does safer, cleaner, abundant nuclear energy provide for urban architecture?

Thesis Statement:
The advancement of nuclear fuel and energy production technologies provides an opportunity for large energy and nuclear byproduct users to be in close proximity to nuclear energy production in the urban public.

Environmental Urbanism:
Distribution networks in cities

Employing advanced reactor technology
Pairing advanced reactor technology with massive electrical consumers requires a new approach to power plant siting. According to environmental engineering specialist, John Winter, the "three E's of power plant siting" are engineering, economics, and environment (Winter, 63). (For the purpose of this thesis, I am taking the engineering for granted based on the reactor technology described and relying upon local and federal investment initiatives currently in place to cover funding.) Of the many factors that influence each of these, he identifies the most integral as fuel, water, and land; without which none of the above can be sustained. Winter subdivides each of these into a number of subcategories that assist in articulating the requirements for a new nuclear complex. Throughout the project I remained highly conscious of these three factors and used Winter's hierarchy as a framework for selecting a site.

Fuel and Waste:
Fuel delivery and waste collection are major determining factors in power plant siting(Winter, 79). Access to federal waste transportation routes, therefore, is one mandatory characteristic of advanced nuclear power plant siting. This is particularly crucial in urban siting situations where less routes are accessible. New York has a number of waste route highways in the outer boroughs and two on the island of Manhattan including Route 9A, along which this project is sited. Unlike Uranium, Thorium reactors can sustain production on one fuel delivery per year(Sorensen, Lessons). This means the need for fuel storage is fairly small and does not demand much supporting space, further supporting the argument for smaller footprints in cities.

Water:
Winter states that the primary concerns relative to water supply in nuclear power plants are 1.) the availability of water for steam generation and for cooling purposes and 2.) the specific needs of water within each reactor, and 3.) the proximity of natural bodies of water and meteorological patterns that may affect levels of groundwater on the site(Winter, 68). While water sources such as rivers, lakes, coastal regions, reservoirs, and groundwater are all viable, each must be analyzed in terms of their potential affect on the site. Fluctuations in groundwater height, availability, temperature, flow, direction, and possibility of contamination are all potential disadvantages to relying on bodies of water(Winter, 69).

Water is of utmost concern for traditional Uranium-fueled Light Water Reactors. In these reactors, water is used as both a moderator and a coolant where the resulting heated water produces steam that generates electricity. During the cooling process, much of the steam is condensed and looped back into the system, but excess process heat and steam is released through large cooling towers(Winter, 69-70). Cooling towers are necessary components of this system play a primary role in the public's perception of a nuclear power plant. Sending gigantic clouds of steam into the air, hyperbolic cooling towers are a signature instigator of nuclear apprehension.

Liquid Fluoride Thorium Reactors demand far less water than Uranium-fueled light water reactors. Using molten salt, an extremely efficient coolant, instead of water, the reactor core becomes highly condensed and the need for large, complex piping and pumping systems is eliminated. ("Molten Salt"). The diminished need for aquatic resources is an additional benefit to the area in which the plant is site and ensures minimal disruption to the existing landscape and ecosystems. This project challenges the role of water in nuclear plants by using heated water and steam to engage and benefit the public while servicing the reactor.

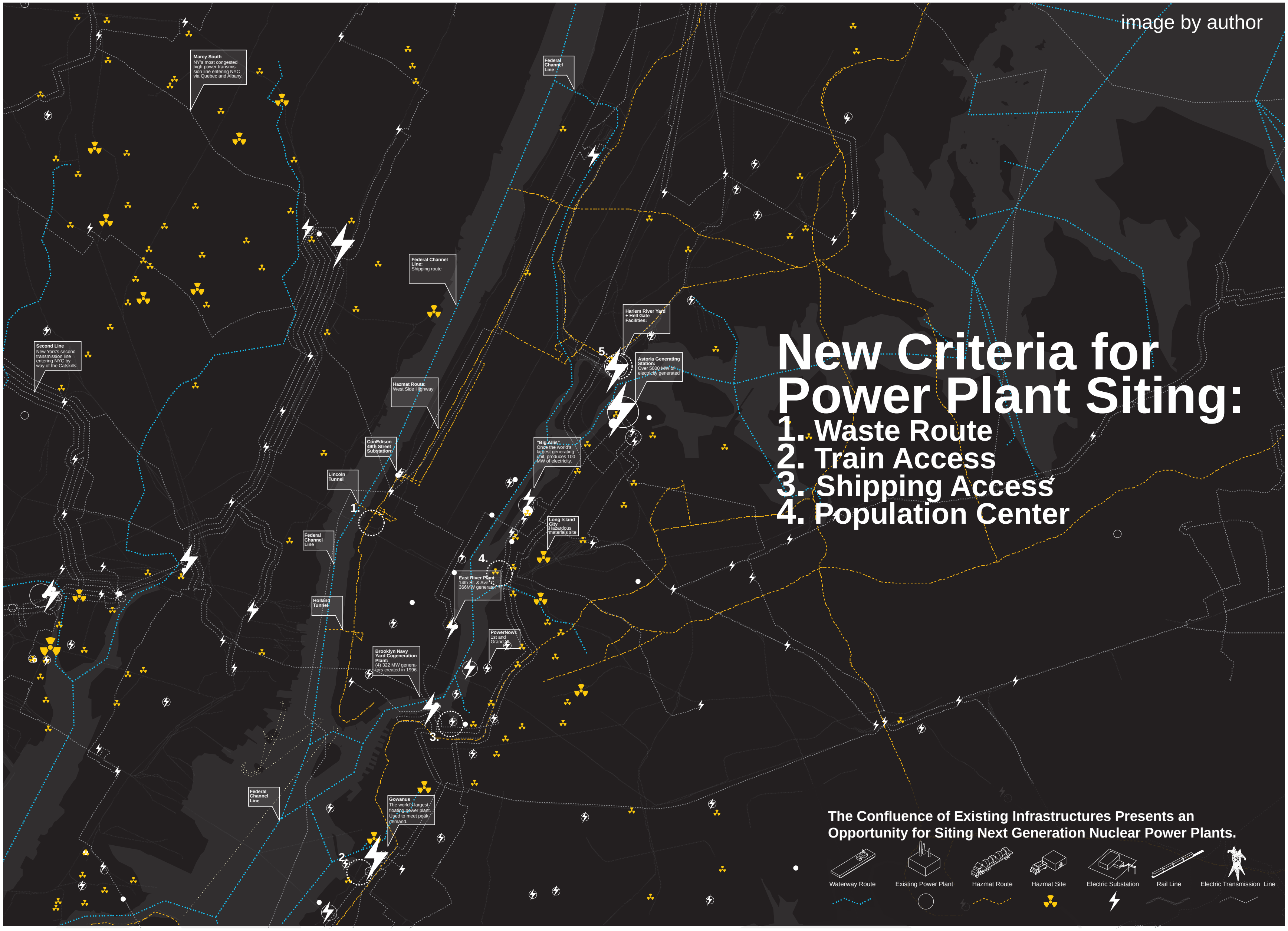
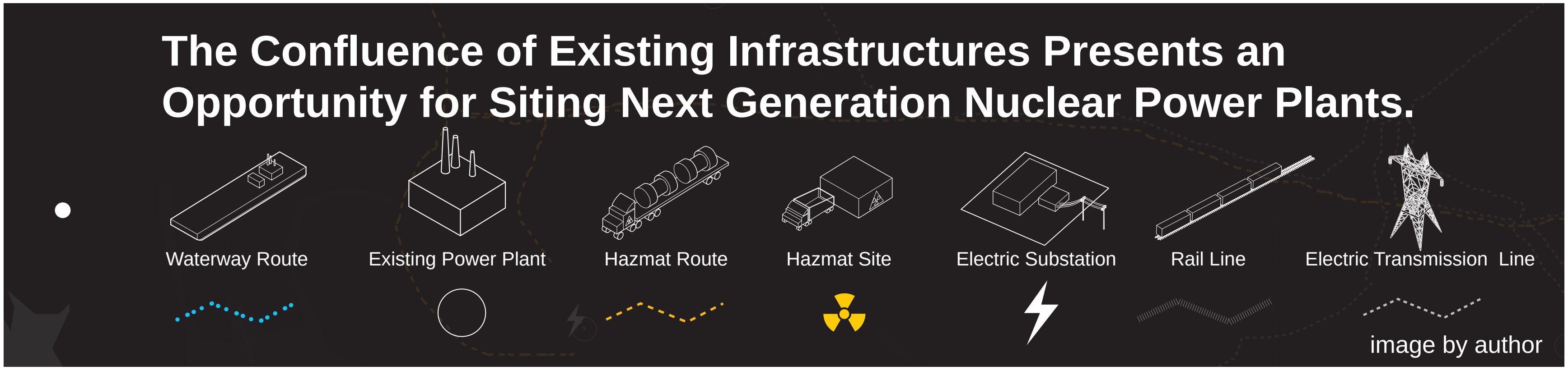


image by author
Marcy South
NY's most congested high-power transmission line entering NYC via Quebec and Albany.
Federal Channel Line
Federal Channel Line: Shipping route
Second Line
New York's second transmission line entering NYC by way of the Catskills.
Hazmat Route: West Side Highway
Harlem River Yard + Hell Gate Facilities:
Astoria Generating Station: Over 5000 MW of electricity generated
ConEdison 49th Street Substation:
Lincoln Tunnel
"Big Allis" Once the world's largest generating unit, produces 100 MW of electricity.
Long Island City Hazardous materials site
Federal Channel Line
East River Plant 14th St. & Ave. C 366MW generator
Holland Tunnel
PowerNow!: 1st and Grand St.
Brooklyn Navy Yard Cogeneration Plant: (4) 322 MW generators created in 1996.
Federal Channel Line
Gowanus The world's largest floating power plant. Used to meet peak demand.
1.
2.
3.
4.
5.
New Criteria for Power Plant Siting:
1. Waste Route
2. Train Access
3. Shipping Access
4. Population Center
The Confluence of Existing Infrastructures Presents an Opportunity for Siting Next Generation Nuclear Power Plants.
Waterway Route
Existing Power Plant
Hazmat Route
Hazmat Site
Electric Substation
Rail Line
Electric Transmission Line

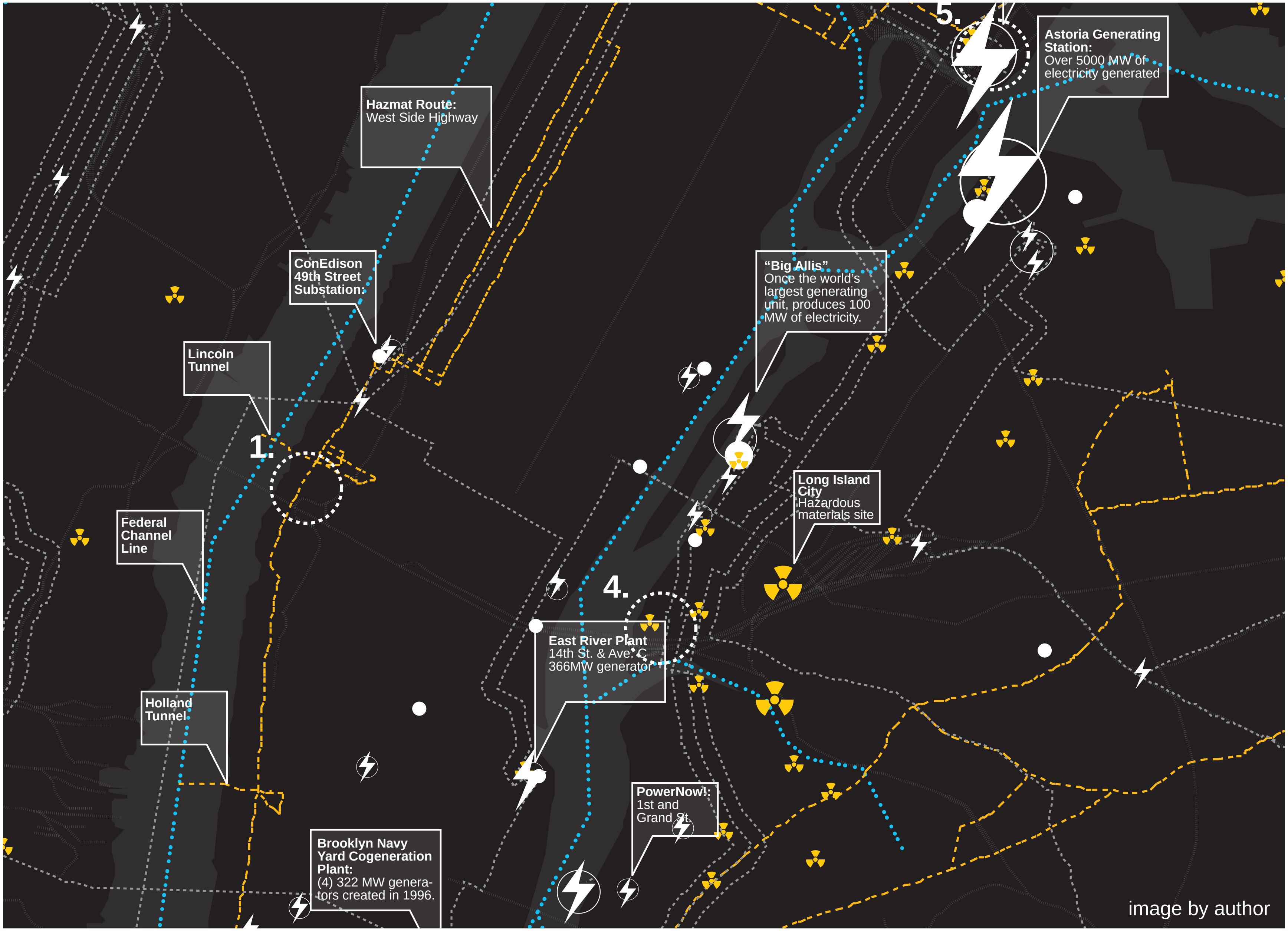

image by author



Land and Accessibility

Traditional nuclear power facilities (including the plant, storage, and auxiliary facilities) occupy 80-100 acres which is 1/10 the size of conventional fossil-fired plants. Liquid Fluoride Thorium Reactors are a factor smaller at only 2-3000 sq ft (Winter, 63). The scale of the complex plays a key role in the siting of the project relative to land. Winter divides "land" into four subcategories: geology, topography / geography, demography, and accessibility(Winter, 77). In dealing with the landscape, particularly relative to these categories, surveying is key. From a geological perspective, one must be aware of the land beneath the surface. Manhattan is ideal in this category as its ground is comprised of Atlantic Shist, a very hard rock. Above the surface the plant must deal with demographics and accessibility. An understanding of population density and available manpower is imperative as there may be as many as 7,000 people working at the peak of construction which has a great affect on the local economy and availability of services(Winter, 78). Winter's final category addresses site accessibility which evaluates all the above mentioned agents relative to human safety and plant operation. The site must be accessible to multiple means of transportation for shipment and delivery of supply and waste. Redundant pathways need to be in place in case of plant shutdown or containment, especially for protection against negligence or terrorist attack in which case monitoring is also a necessity(Winter, 81). Therefore, in addition to the siting requirement for 1.) waste route adjacency, I have required that the new nuclear plants must be sited 2.) on federal shipping channels, 3.) with access to train ways, 4.) in population centers, and 5.) with access to existing energy-dispersing infrastructures.

Power plant siting requirements:
1.adjacency to federal waste route
2.adjacency to federal waterway
3.access to train ways
4.in population center
5.access to existing energy-dispersing infrastructures



5.
Astoria Generating Station:
Over 5000 MW of electricity generated
Hazmat Route:
West Side Highway
ConEdison 49th Street Substation:
"Big Allis"
Once the world's largest generating unit, produces 100 MW of electricity.
Lincoln Tunnel
1.
Long Island City
Hazardous materials site
Federal Channel Line
4.
East River Plant
14th St. & Ave. C
366MW generator
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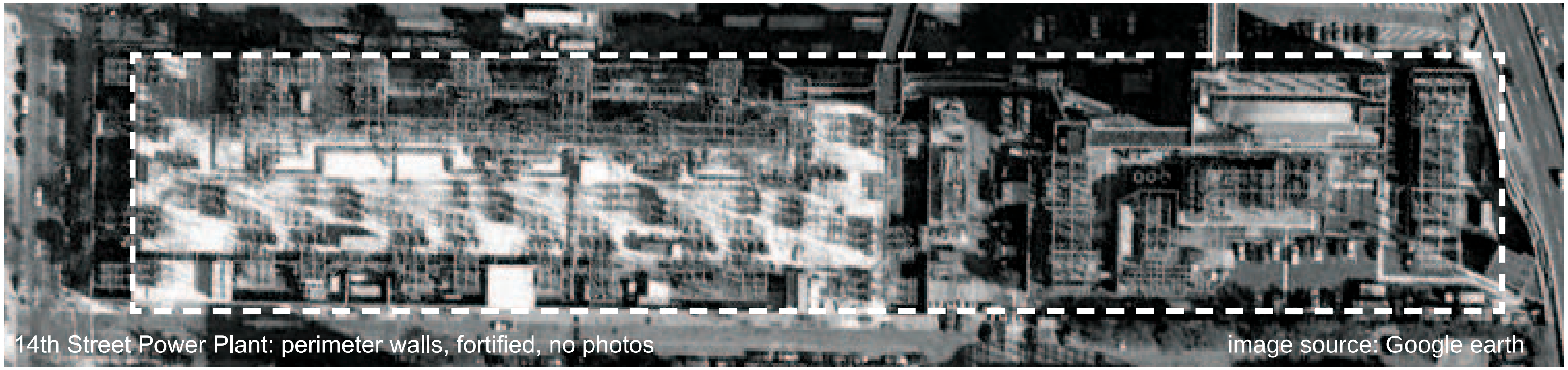
PowerNow!:
1st and Grand St.
Brooklyn Navy Yard Cogeneration Plant:
(4) 322 MW genera-tors created in 1996.
image by author



Local Power Precedents

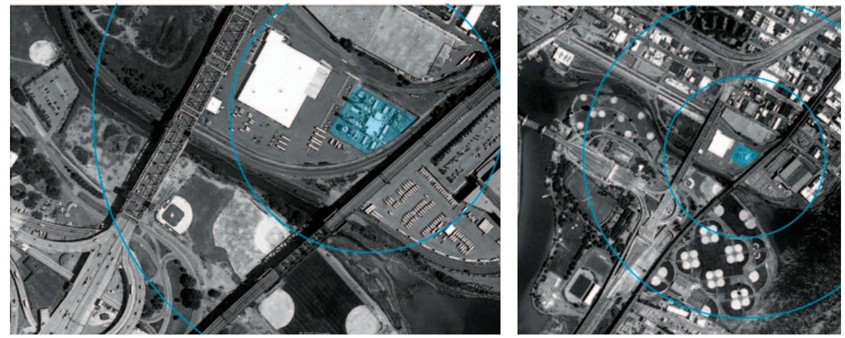
While New York City does not currently have any nuclear power plants within its boroughs, in recent years NYC has challenged traditional power plant siting with a series of small, compact units in a system named PowerNow! PowerNow! is a initiative established by the New York Power Authority in 2001 in response to a series of predictions forecasting power demand increases and overloads in the coming years(PowerNow!). The response was a ten month, fast-track design and implementation of new generators consisting of six sites throughout New York City and one in Long Island. The implementation of these plants reduces the load of older oil and natural gas fueled plants throughout the city and replaces them with a clean energy solution. In 2003, these power stations helped return power to the city during the August 13 blackout. The units proved their worth again during the September 11 attack when the New York Independent System Operator (NYISO) limited the delivery of electricity from upstate plants into the city(PowerNow!).Vernon Blvd, 2 Units
North 1st and Grand Ave, 1 Unit
3rd Ave and 23rd St, 2 Units
Pouch Terminal, 1 Unit
Harlem River Yards, 2 Units

TThe stations are unassuming; placed in industrial zones along the water's edge, their compact size does little to disrupt the landscape. The North 1st and Grand St. station is bounded by a small park and a few warehouses converted into loft living. A ten foot fence and coils of barbed wire separate the pedestrian from the gravel courtyard of transformers. A grey mesh is zip tied to the inner side of the fence, obstructing a direct view of the equipment beyond. A single cooling tower protrudes above the rectangular site but is only feet away from picnicking hipsters in the park. No one seems to notice or be bothered by the plant. The rumble of the turbine is quite present, but can easily be drowned out by a passing truck. The noise steps up a notch as something else occurs inside, but remains at a level of exterior white noise. There are no guard stations or patrolmen, no visiting trucks, but simply a few mobile trailers next to the generation building.

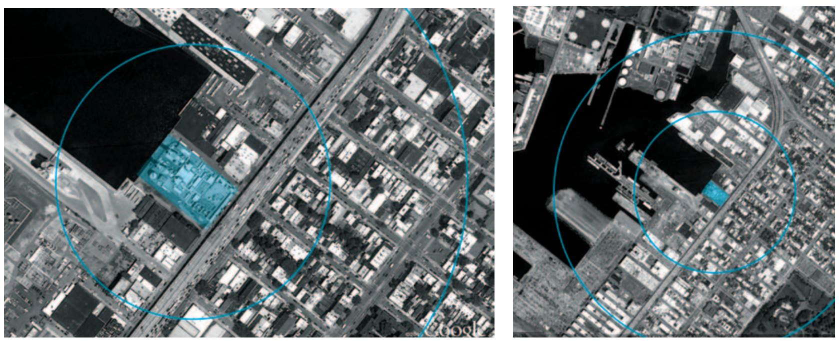
In contrast, the 14th Street Con Edison Station operates at quite another scale. The station intercepts 14th Street with a large blue operable gate and guard station. (Three operators came out while I was taking pictures, threatened to call the police and made me "delete" my photos. I motioned in the direction and pressed a number of buttons, including the trash button, but only once, and that seemed to satisfy them.) The station takes up an entire city block in depth and runs from 13th to 15th Streets. The block between 13th and 14th is packed with transformers while the generation station spans the entire block between 14th and 15th. Con Edison support, maintenance facilities, and supply truck parking stretch all the way to FDR Drive.

PowerNow! Facilities in NYC

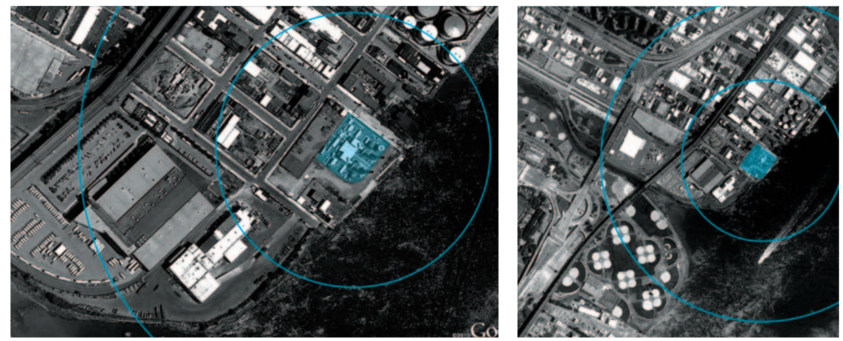
1. 1st St + Grand St Brooklyn: 1 Unit.



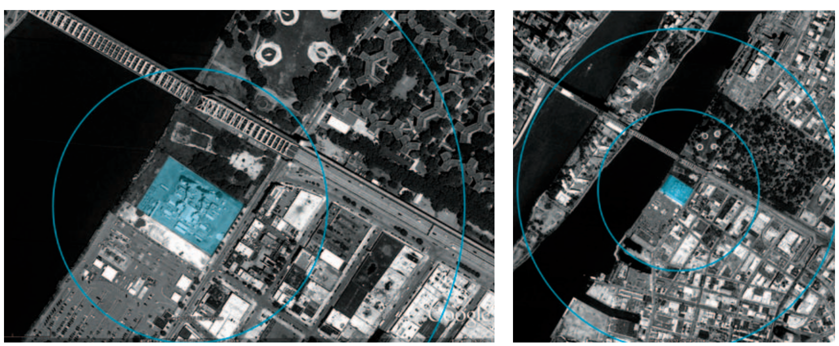
2. Harlem River Yards Queens: 2 Units.



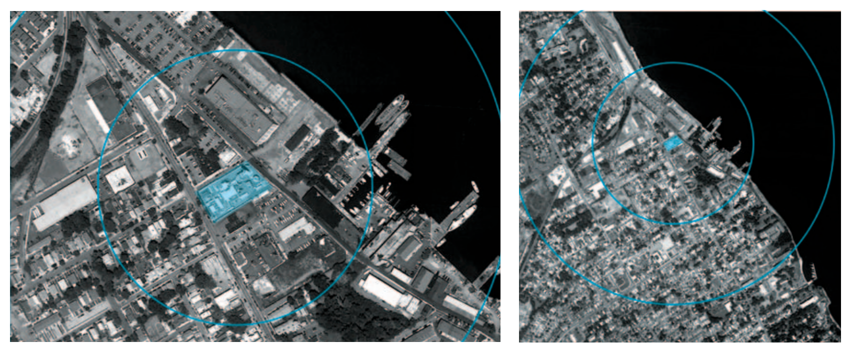
3. 3rd Ave + 23rd St Brooklyn: 2 Units.



4. Hells Gate Queens: 2 Units.



5. Vernon Blvd Brooklyn: 2 Units.



6. Pouch Terminal Staten Island: 1Unit.

image source:
Google earth

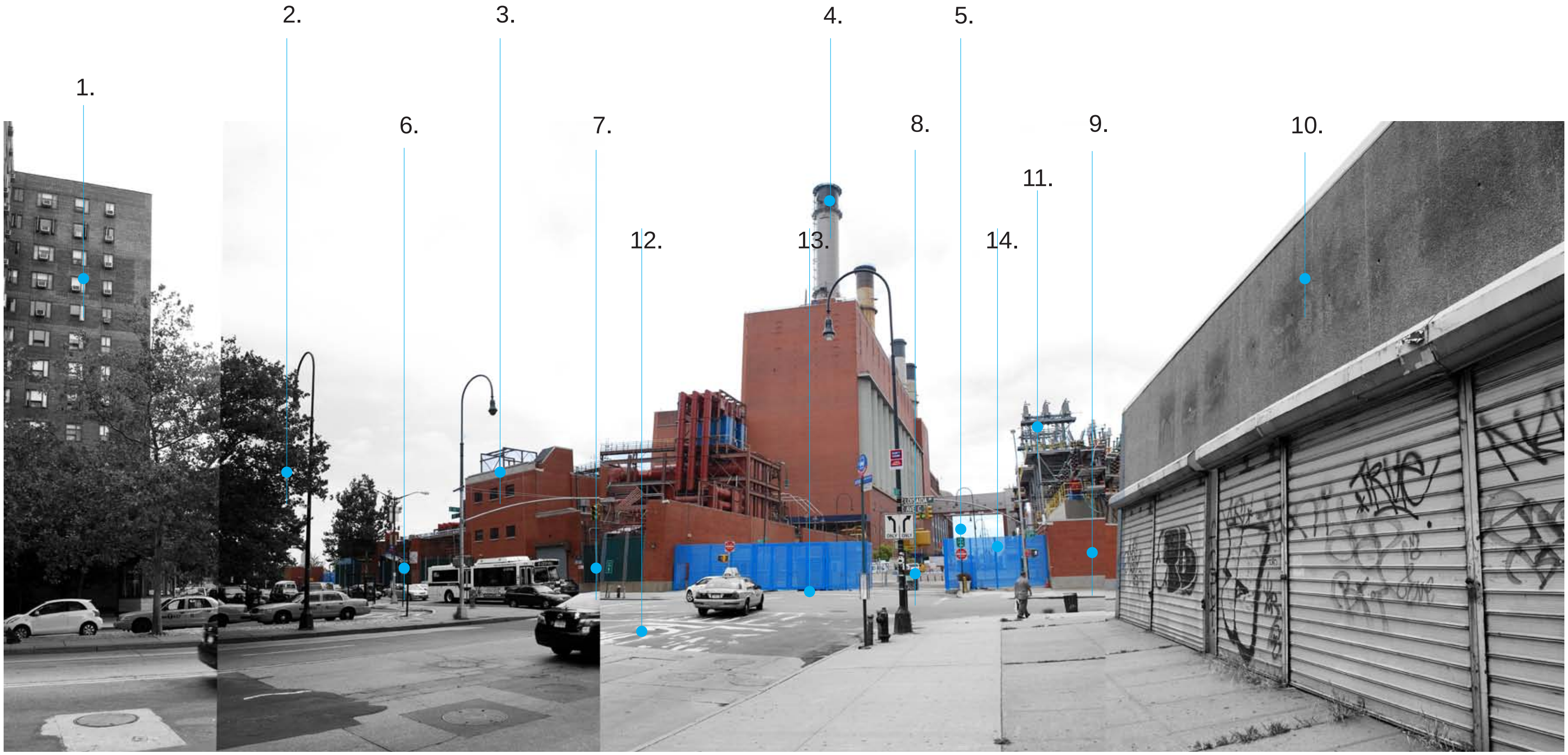


image by author

14th Street Power Plant:
Contextual Analysis

1. low-income housing
2. bound by major highway + river
3. caged roof access
4. cooling towers
5. covered, connected access to all facility buildings
6. street-accessible offices and control center
7. controlled freight entrance off main street
8. manned entrance gate with guard station
9. security and visual barrier: 10' brick wall with barbed wire
10. abandoned / vacant defaced storefronts
11. adjacent substation
12. controlled traffic intersection
13. obstructed view security access gates
14. industrially lit exterior

image source: http://lh6.ggpht.com/_FI7D2XTrOSA/ScaVX95MpcI/AAAAAAAABU8/-_xl8uRkbRU/IMG_8996.JPG

Safety:

Buffer Zones:

Safety is a primary concern for siting a nuclear power plant. Both technical and social concerns have established guidelines for the standard siting requirements of such a facility. The existing model for nuclear power plants in American requires a 14 mile radius buffer zone around the uranium-powered reactor(Winters, 66). This boundary can be mapped by drawing lines around the site plan of the reactor site, and possibly seen through development boundaries, building trends, or simply by tracing boundary fences. This boundary cannot be reduced to a singular line or identified by a material of structure, but is rather, defined by a series of layers, ranging from the innermost reactor core wall to the first plot of land owned and operated by another party. The LFTR, however, has self-regulating functions built within in, eliminating the need for a safety buffer zone around the plant(Sorensen, Lessons). This reduction of a boundary, from 14 miles to a few feet requires a new conception of this buffer zone. How does one draw a line between a contentious facility that is typically mitigated by distance, to one that compresses these layers of separation (both physical and social) to one that can be measured in the span of a room or a wall? What happens to these layers in their compaction? This reduction of elements into a singular surface can be seen, in a sense, as a form of camouflage. Redefining a buffer zone at the scale of architecture is a core branch of this project. This calls to question distance, comfort, and disguise. What can architecture do to challenge this notion? How does it utilize the surrounding site to aid in this motive?

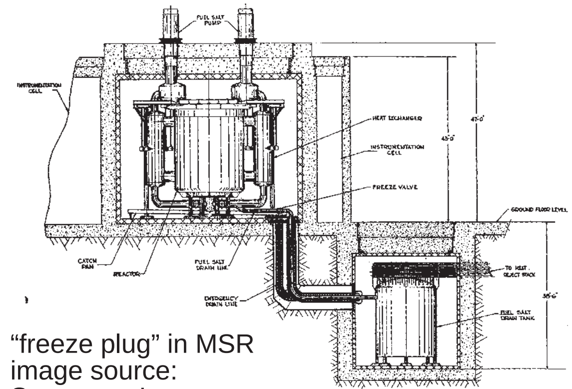
Safety and Architecture
Smaller, Safer, More Efficient Reactors

In David Walters; “Towards a Thorium Economy,” Walters outlines the many benefits of Liquid Flouride Thorium Reactors (LFTRs) and Molten Salt Reactors (MSRs) in comparison to standard uranium-fueled Light Water Reactors (LWRs). In reference to scale, LFTRs are much smaller than LWRs per MW for a number of reasons. Firstly, LFTRs run at atmospheric pressure so the surrounding mechanical infrastructures and containment buildings do not have to be as “robust” since there is not any high pressure in the reactor itself. Walters additionally states that current proposals suggest placing the reactors underground or underwater to “further reduce [the reactors] above ground profile and reduce engineering costs.” By using inert gas instead of molten gas, the pipes and turbines will be smaller than existing models due to their higher thermal efficiency(Walters). The key component that makes MSRs safer, is something called a “freeze plug(Sorensen, Lessons).” A freeze plug is “an open line where a frozen plug of salt is blocking the flow,” which is kept frozen by an external cooling fan(Sorensen, Lessons). Even in a total power loss, the plug would melt, causing the core salt to drain “into a passively cooled configuration where nuclear fission is impossible(Sorensen, Lessons).” Therefore, not only are the advanced reactors proven to be smaller, and use safer fuel, they are also not susceptible to nuclear meltdown.

Safety is clearly a priority for any energy generating complex. Historical precedents have shown what can happen to an environment when proper measures are not taken in plant operations, security, mechanical performance, or even poor employee performance. Assuming that the operational mishaps are at a minimum due to the advanced nuclear technologies outlined above, the nuclear campus must still ensure prime operational and structural capabilities. Measures must be taken to protect volatile materials, equipment, employees, and operations from foul play or environmental disaster. Traditional American nuclear power plants are separated from development by miles of land barriers and massive containment buildings. However, structural tests have shown that the walls of containment buildings alone are strong enough to withstand the impact of a jet. So how does one contain the mechanics and operations of an urban nuclear power plant to protect them from both individuals and environmental disaster while simultaneously providing access to those who need direct access to it?

Designing the Barrier

Protecting architectures of power, whether energy-generating or political, has long informed the shape of the architecture(see Fortification, page 112). From concentric arrangements to earthen-bound structures, various protective intents have produced a wide array of formal responses. Containment Building employs a series of eight LFTRs throughout the nuclear campus. In addition to providing electricity to the city, each reactor core is dedicated to a specifically catered nuclear program. Smaller

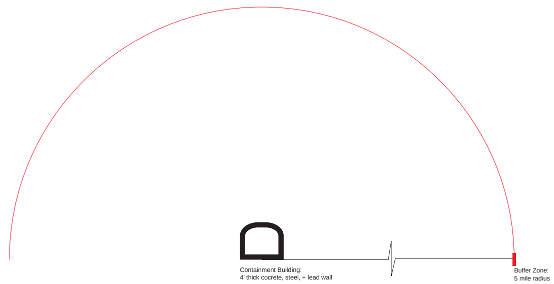


“freeze plug” in MSR
image source:
Sorensen, Lessons

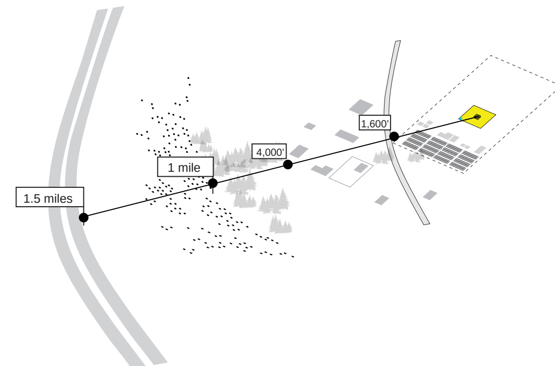
“The key component that makes MSRs safer, is a freeze plug. ...Even in a total power loss, the plug would melt, causing the core salt to drain “into a passively cooled configuration where nuclear fission is impossible.”

Sorensen, Lessons

tubes, containing more secure spaces, are concentrated around the core. As you venture further away from the core (plannometrically) the bundled tubes get larger and more public. Each of the cores is composed of its own, dedicated bundle. Each of the eight reactor-core bundles throughout the building are grouped again as a super-bundle to support the overall structure. Access to the reactors themselves is only achieved through the below-grade service floor, which in itself, is a highly secured, single-entrance area. As



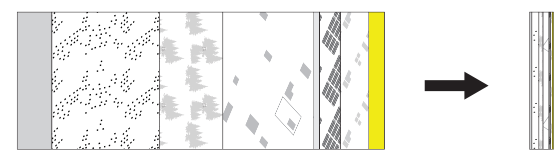
typical buffer zone



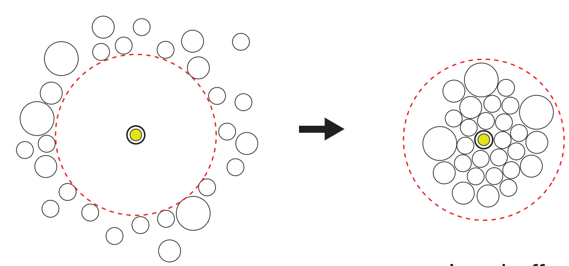
buffer zone diagram

the bundles protrude through the building, they are carved and hollowed to allow light and circulation through the building. The main hall is a grand public promenade, marked by an inverted conical carving of the bundles to produce large spans of open, public space. The thinnest line between the public and the reactor core may only be a few feet at any given time, but a connection beyond the thinness of that containment wall is an elaborate series of paths and security that prevents direct access. Containment Building is indeed a series of complex, secure juxtapositions that play upon traditional notions of concentric, secure stratification to obfuscate access while at times relying on the primal concrete and steel wall that not even a jet impact can budge.

While nodding to the precedents of physical, political, and environmental powers, Containment Building is a revolutionary typology that redefines the architectural language of both sustainable energy and political prowess. It is stubborn to protect its interior as well as the landscape around it, but dares to express its technological advancement architecturally. The power plant is a symbol of endurance, intelligence, and sustainable progression.

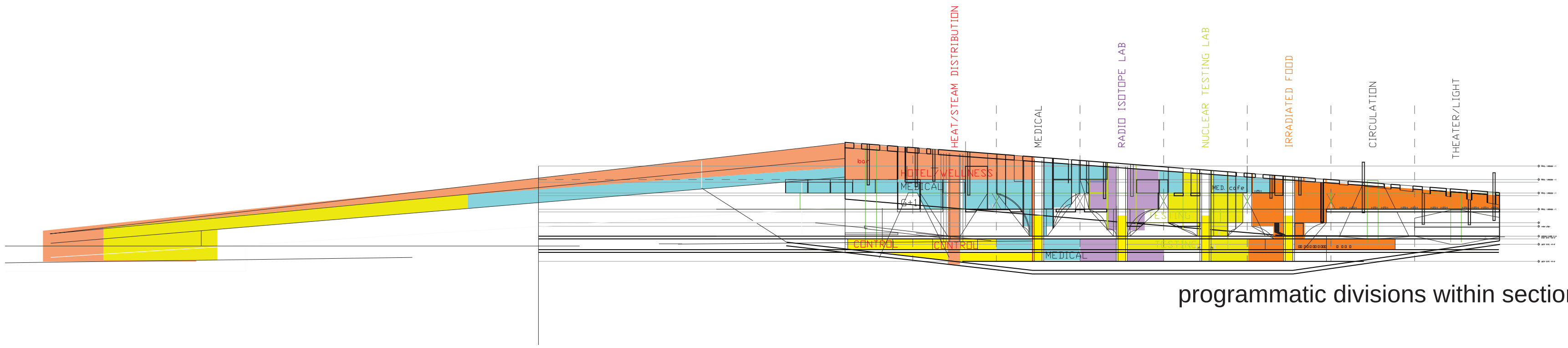


buffer zone challenge

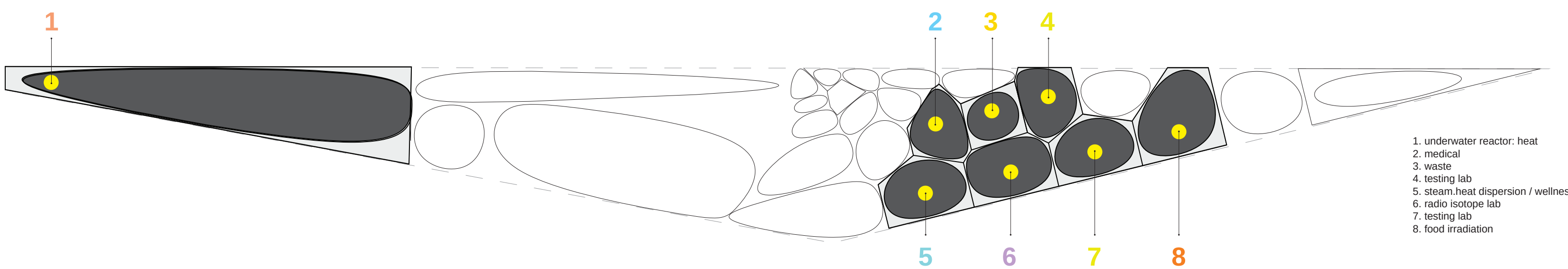


program as nuclear buffer

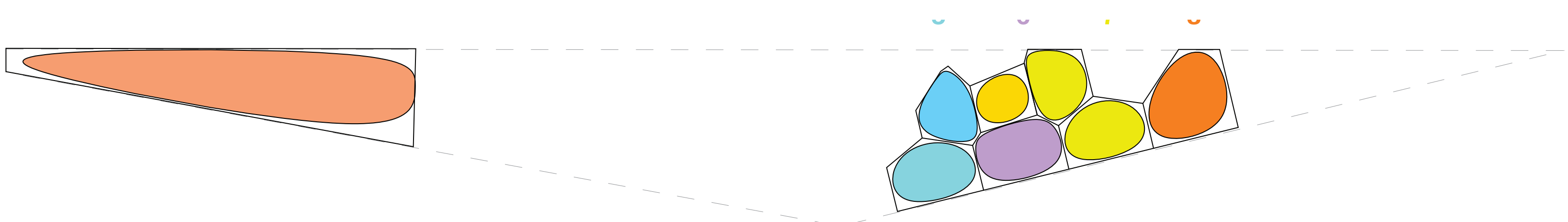
page illustrations by author



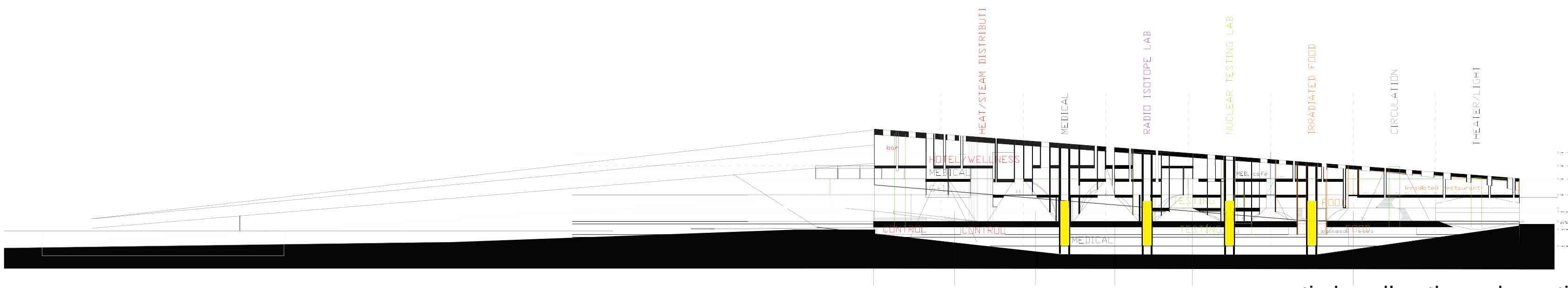
programmatic divisions within section



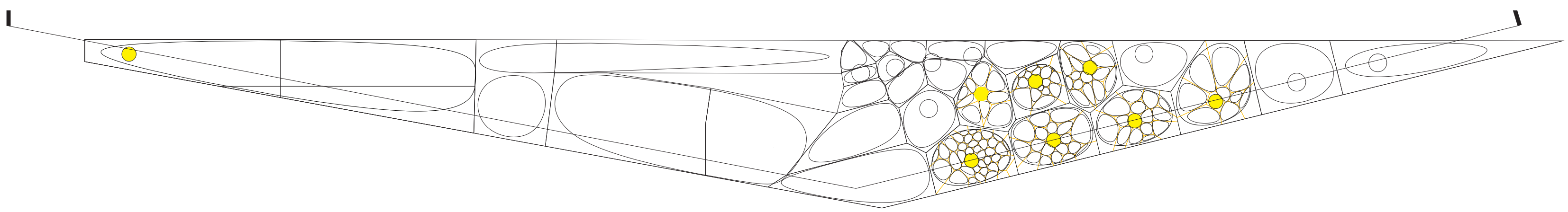
reactors within program-specific bundles



reactors within program-specific bundles



programmatic bundles through section

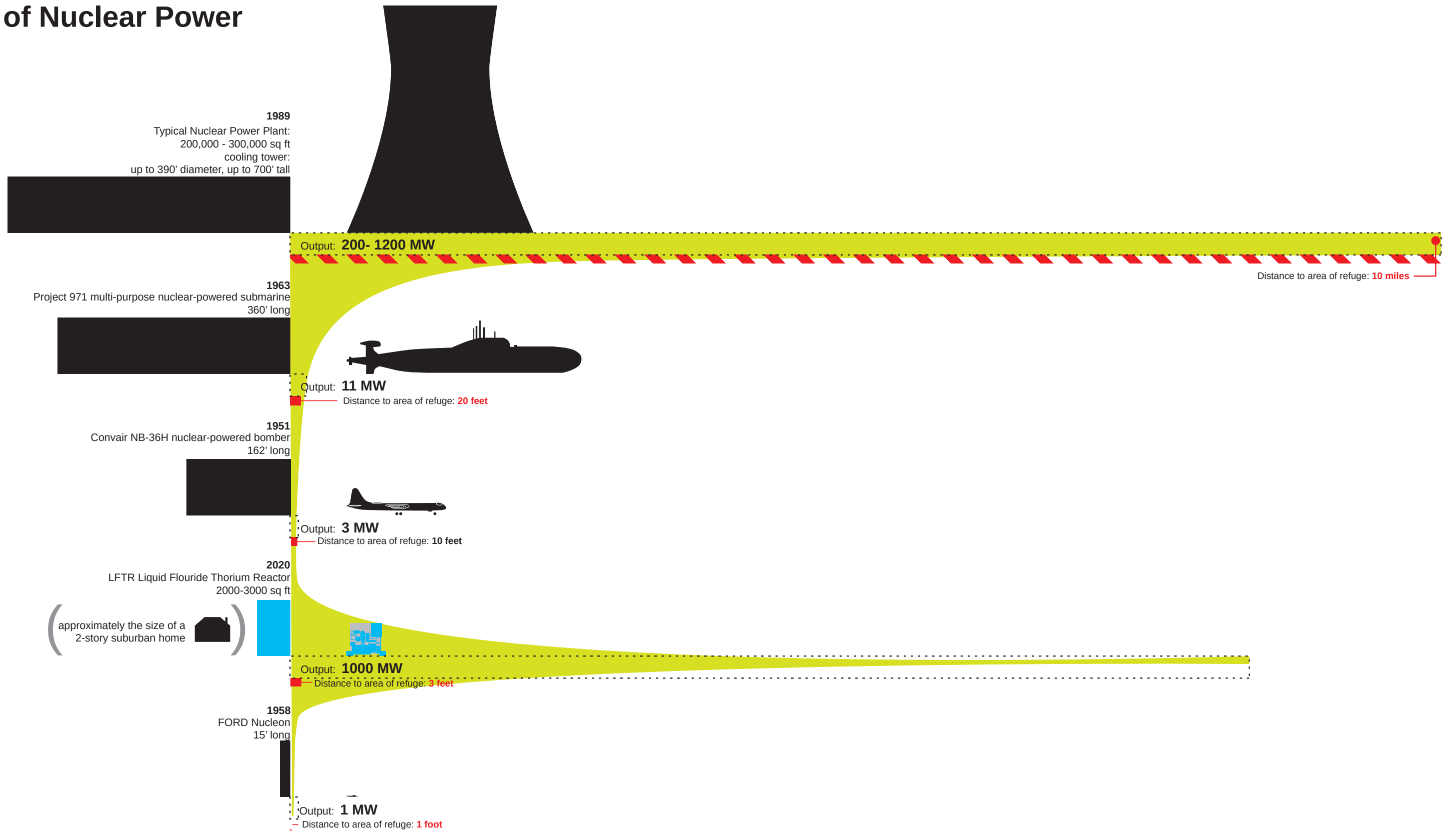


reactors within program-divided bundles

images by author

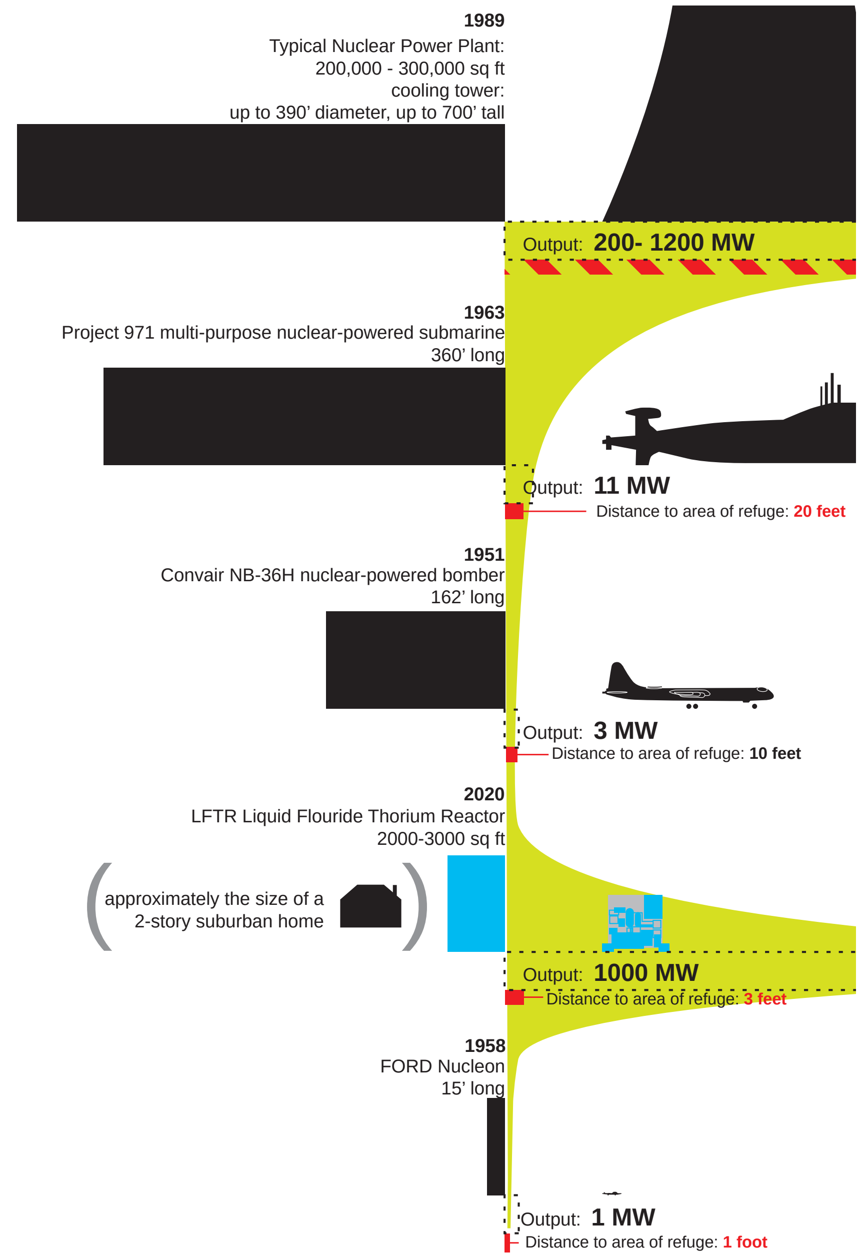
The Changing Scale of Nuclear Power

images by author



Military Precedent

The atomic era boasted promises of electricity so abundant that it would be free. This spurred a series of idealistic inventions powered by nuclear fission. While concept vehicles like Ford's Nucleon did not come into fruition, the B-36H Bomber was fundamental to the LFTR development. The first LFTR was created as a lightweight, long-lasting power generator for the bomber(Sorensen, Lessons) which flew for over 100 hours. As reactor size diminished and power increased, innovations like the the NS Savannah, a civilian vessel, and even the United States' Nuclear Navy fleet of over 180 submarines and warships became possible. These inventions were particularly significant in the advancement of nuclear power facilities relative to their drastic reduction in reactor size and prioritization of safety. The self-regulating components of this reactor eliminate a need for a buffer zone around the nuclear complex(Sorensen, Google). This challenges previously conceived requirements for proximity, location, and accessibility to nuclear facilities. Additionally, Another supporting precedent, the military employed compact, mobile reactor laboratories to power remote locations in the Arctic. Compact reactor technologies have existed for years and are continuously being improved upon. By securing the same nuclear advancements for commercial civilian use, the future of nuclear power will be forever changed.

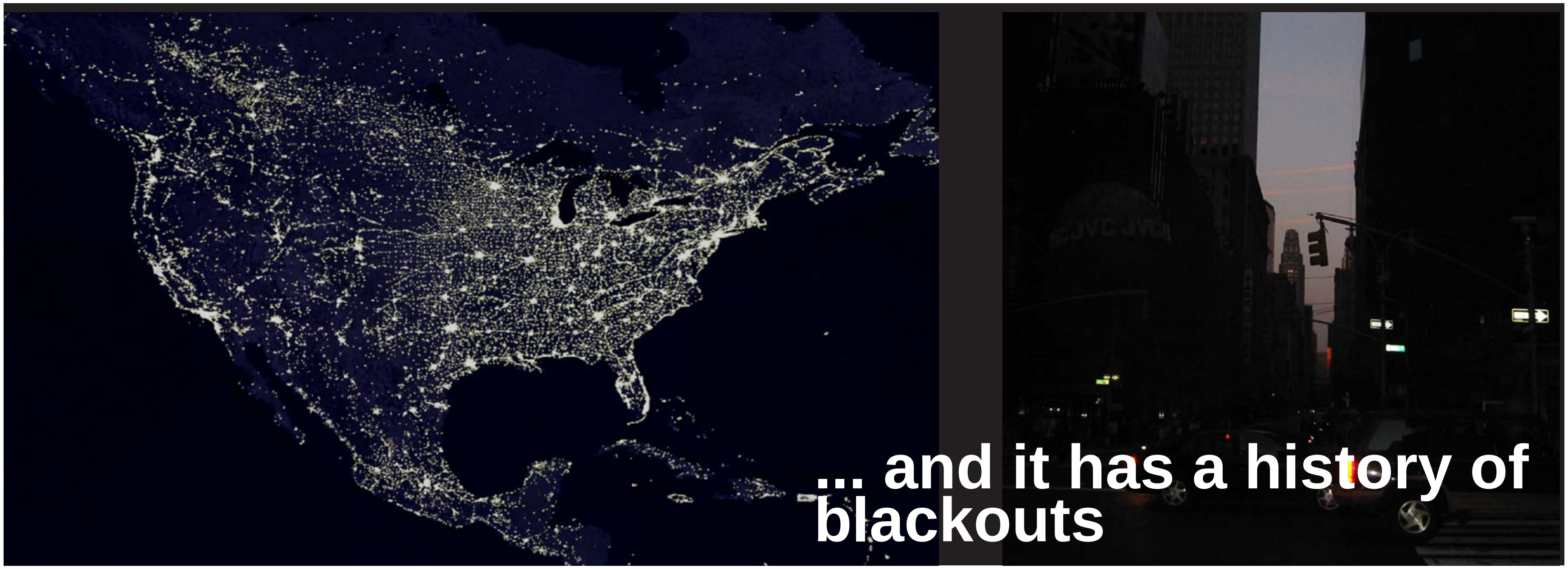

1989
Typical Nuclear Power Plant:
200,000 - 300,000 sq ft
cooling tower:
up to 390' diameter, up to 700' tall
Output: 200- 1200 MW
1963
Project 971 multi-purpose nuclear-powered submarine
360' long
Output: 11 MW
Distance to area of refuge: 20 feet
1951
Convair NB-36H nuclear-powered bomber
162' long
Output: 3 MW
Distance to area of refuge: 10 feet
2020
LFTR Liquid Flouride Thorium Reactor
2000-3000 sq ft
(approximately the size of a
2-story suburban home)
Output: 1000 MW
Distance to area of refuge: 3 feet
1958
FORD Nucleon
15' long
Output: 1 MW
Distance to area of refuge: 1 foot

New York, NY:

The most populous city in the U.S, NYC is also one of America’s most energy efficient cities per capita...

Population: 8.4 million

image source: top: http://www.pentaxforums.com/gallery/images/7801/1_IMGP7068_Pentax.JPG
bottom: Googe Earth



... and it has a history of blackouts

image source: left: http://www.noaanews.noaa.gov/stories/images/usa-nightlights1994-1995.jpg
right: http://farm4.static.flickr.com/3636/3574040968_0f1aa2e115_o.jpg

"New York City has adequate electricity resources today, but only by a slim margin. A projected increase of approximately 1.5% annually in electricity demand in the next five years will necessitate new generation and transmission facilities and expanded distributed resources measures. Additional resources will be required to assure market price stability, and old power plants will need to be retired and/or replaced with cleaner, more efficient facilities..."

A Report to Mayor Michael R. Bloomberg:
New York City Energy Policy: An Electricity Resource Roadmap
Prepared by the New York City Energy Policy Task Force

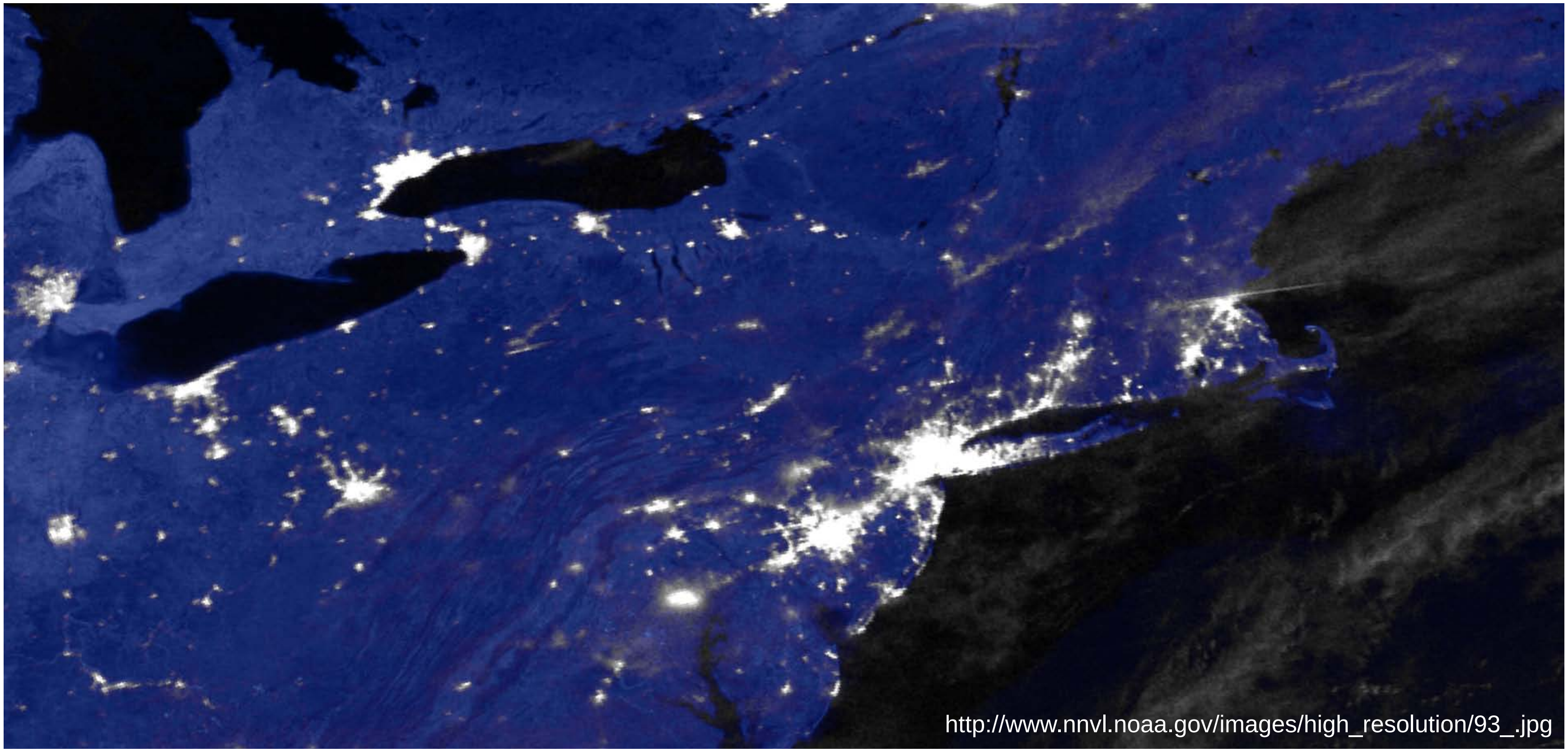
New York State Electric Network + Waste Routes
image by author

Urban strategy

The final site selection in New York City resulted from a combination of a series of nationwide mapping filters I combined with the specific set of site criteria. I first cataloged the top energy consuming cities in the United States and mapped them relative to population centers, fuel locations, major electric transmission lines, waste routes, and coastal proximity (to see full extent of site-searching maps, see page 122).The new criteria for siting an advanced nuclear power plant: 1.) adjacency to federal waste routes, 2.)adjacency to federal waterway, 3.)access to train ways, 4.) in a population center, 5.)access to existing energy-dispersing infrastructures, was used to find specific building sites within a city. I decided on New York City, America's most populous city and America's sixth highest energy consumer for its size, population, progressive energy politics, and history of electrical mayhem.

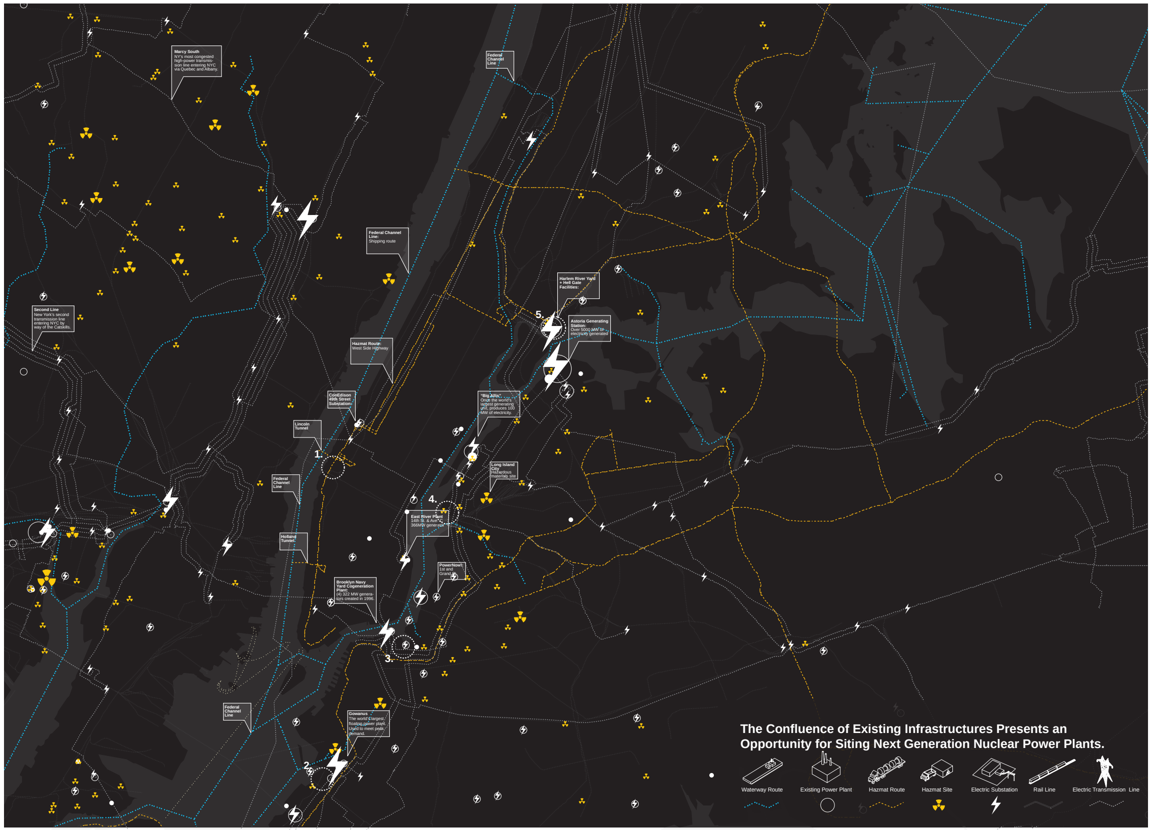
Applying this Technology to a City in Need

During The Northeast Blackout of 2003, millions of people across the northeastern United States a parts of Canada lost power for anywhere between 6 hours and 2 days. The problem was rooted in Ohio but sequentially shut down power over 500 miles away throughout the entire state of New York, including all four of its nuclear power plants. In New York City and its surrounding area, affecting over 14 million people. Public transportation stopped, communication services were down, and elevators ceased in their cores. The mid August heat forced people out of buildings



and onto the streets and with pressure pumps debilitated, all running water was lost. The entire city, in and out of buildings, ceased to perform. The inter-connectivity of power generation systems and redundant supply networks had backfired, taking the entire system down. In years following the blackout, there has been a conscious prioritization of locally produced energy. Today, local power supply companies are promote In-City Generation Projects that advertise “clean energy” generation by burning natural gas. However, these systems are few and far between: they require sizable plots of land, and the the burning of fuels force them into industrial districts. There is a clear need for this localization of energy production and independence from larger energy networks. With an ever-increasing urban population, electricity demands increase yearly, burdening the larger network and putting cities at risk of potential blackouts. Electric transmission capacity to New York City has not been increased since the 1980s, with the last significant upgrade to the system in New York State was the Marcy-South project running from the Utica area into downstate in 1988, allowing the importation of more power into the City (New York City Energy Policy). The reliance on distant networks is not a sustainable approach for future energy supply. Electrical power cannot easily be stored over extended periods of time and is generally consumed less than a second after being produced. Local energy production is therefor more cost-effective and efficient. The key to local production, however, is to have the highest energy output with the least environmental impact. Compact LFTR's are a viable solution. Each 1,000MW reactor is only 2-3,000 sq ft with the overall containment vessel only slightly larger. At energy consumption levels predicted for 2030, eight of these advanced, compact reactors could power all five boroughs.

This project proposed a New York powered 100% by nuclear power. Five proposed sites, situated across the boroughs, will form New York's new nuclear network. Each site will be responsible for 1/5th of the city's power and contain a series of eight compact, coupled LFTRs. The sites include: 1.)Harlem Yard, 2.)Gowanus Yard, 3.)Navy Yard, 4.)Long Island City, 5.)11th Avenue and 34th Street . The selected site for this project is site #5. While complying with the standards established for power plant siting, it has contextual benefits of being on the future subway extension of the #7 line, it is in close proximity to highly populated programs such as the Jacob Javits Convention Center, the Intrepid Museum, the Highline, on the Hudson River Greenway, and is adjacent to major commercial development projects such as the proposed site for the Olympic Stadium.



New Power Plant Siting Criteria
image by author

5 Stations to Power New York City

The power plants generate enough electricity to power all five boroughs, promoting New York City to electric independence.

image source: Google Earth

1. **Harlem Yard Station**

2. **Gowanus Station**

3. **Navy Yard Station**

4. **Long Isand City**

5. **11th Ave. + 34th St.**

1. Harlem Yard Station

2. Gowanus Station

image source: Google Earth

3. Navy Yard Station

4. Long Isand City

5. 11th Ave. + 34th St.

image source: Google Earth

Site:

On future extension of the #7 Subway line.

Located along nuclear waste transit route.

Close proximity to highly populated buildings and program: Jacob Javits Convention Center, Circle Line tours, the Intrepid Musem.

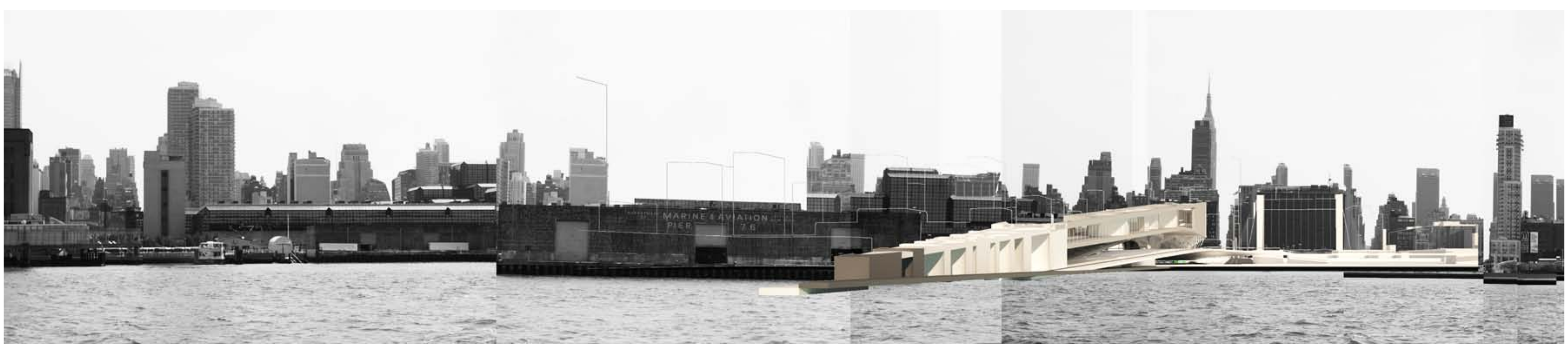
Terminus of the High Line.

Adjacent to west side hike and bike trail.

Sited on the Hudson River.

Adjacent to commercial development project (proposed location for Olympic Stadium).


image by author



3. Containment Building

Site strategy: location, location, location

Midtown West is an orphanage for the large architectural oddities of Manhattan. The Jacob Javits Convention Center, Madison Square Garden, the Hudson Rail Yards, and down to the water's edge, the Lehigh Building all occupy an entire city block or multiple. These widespread architectural behemoths are contextually rare in the Manhattan landscape; skyscrapers flock around the dense Manhattan Shist of Midtown and Battery Park, leaving earthen densities and the urban masterplan to determine the height gradation between the dense center and the coastline. The Hudson area rests primarily upon coastal plain deposits, it is marked topographically by a drastic drop in elevation amidst a city that is primarily conceived of as flat. A drastic drop in elevation along 10th Avenue severs the development to the east from the west. Between the topographic schism and the once industrial river edge lies a series of large, commercial and industrial buildings and industrial lots. The architecture is marked by large, windowless boxes and heavy trucking traffic. The expansive rail yard distances the pedestrian from both architecture and park, the sky is threateningly open above. The streets between the large structures and vast yards cavernously consume the pedestrian. It is a place where only bigness feels at home.

The water's edge is activated by tourist and resident attractions alike. Large cruise ships, the Intrepid Museum, Circle Line tours, and Chelsea Piers all extend architectural bigness into the water, drawing crowds through the mega structure-littered landscape between Penn Station and the Hudson. Active residents bike, blade, and jog up and down the dedicated paths that echo the edge of the Hudson and the West Side Highway. This north-south activity further isolates the mega-lots between midtown's 10th and 12th Avenues.

The extension of the No. 7 subway line to 11th Ave and 43rd St. and the Hudson Yard Redevelopment Project attempts to bridge the life of the city with the concrete devastation that stretches the two avenue blocks between the active waterfront and the heart of The City. Without an appropriate architecture, subway riders will be ejected onto the concrete sea of the truck-lined 11th Avenue. The 11th Avenue Station will be tied to a building activated by tourists, residents, and researchers alike.

View from New Jersey looking East
image by author

Figure Ground
image by author

Site Section Looking East
image by author

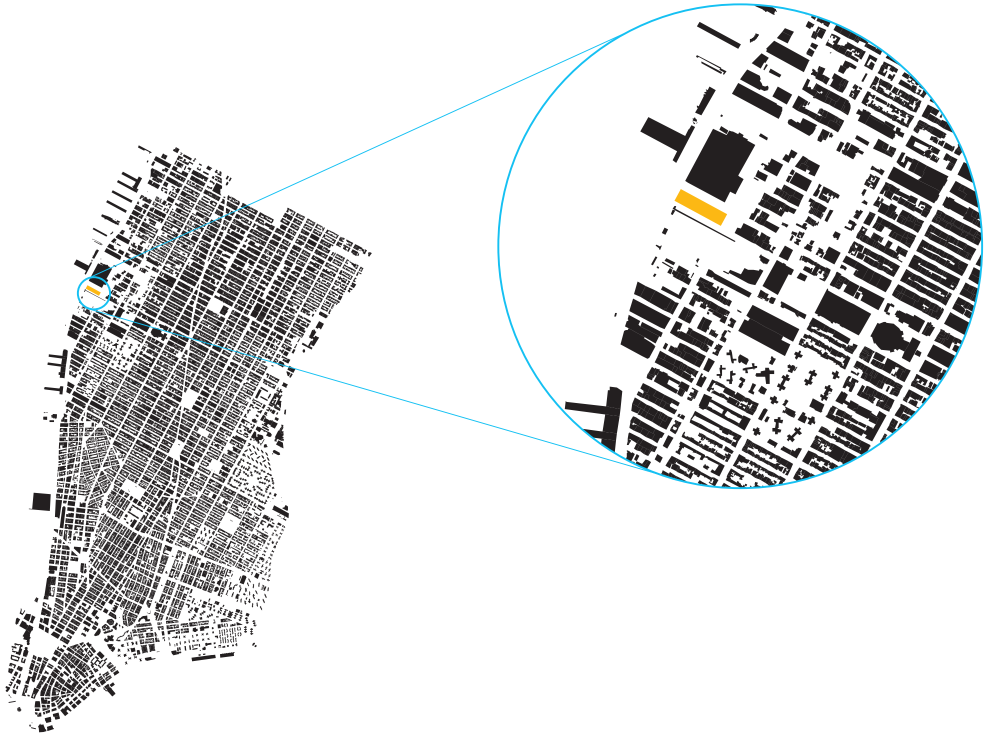
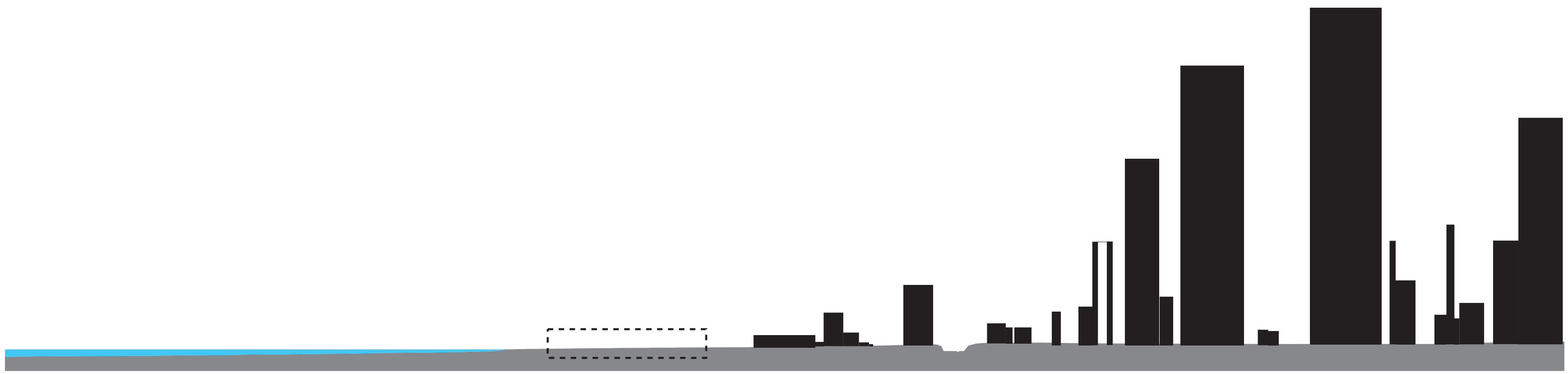


Figure Ground
image by author

Site Section Looking North
image by author



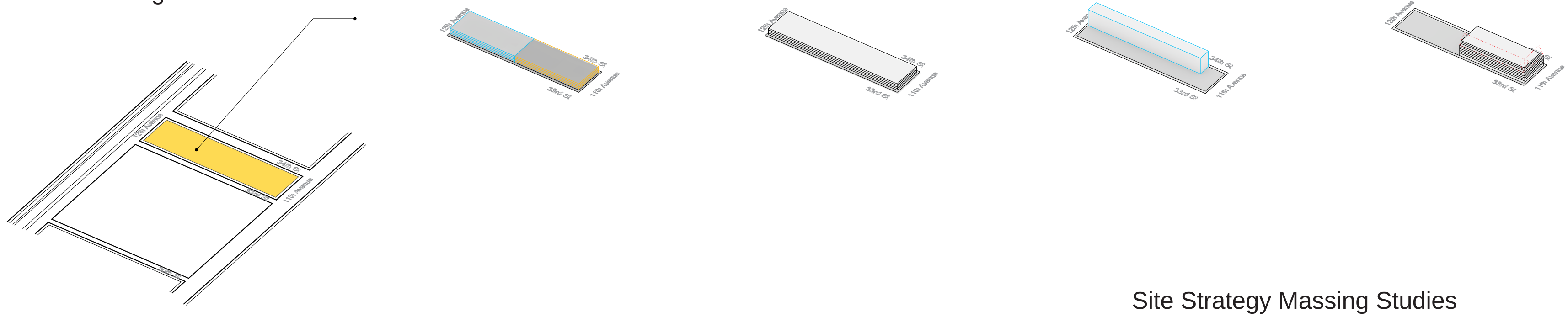
New York City Zoning

Manhattan: Clinton District

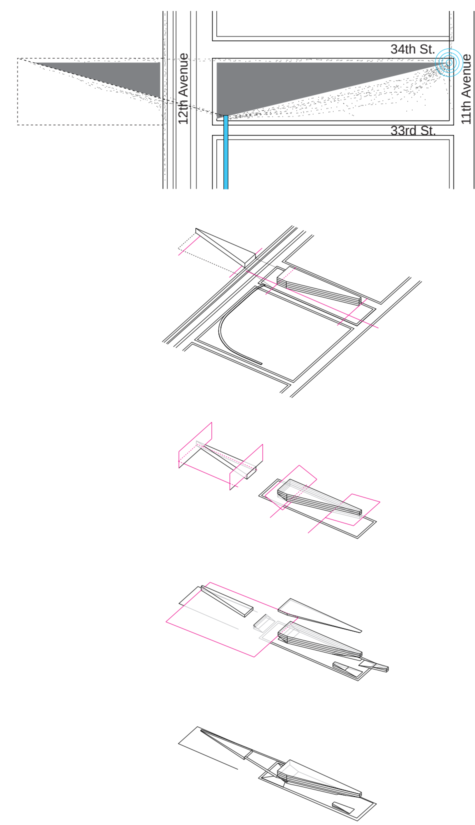
M2-3 Manufacturing FAR: 2
Commercial FAR: 2

image source: NYC Zonig Map

M2-3 Massing Studies



Site Strategy Massing Studies



page images by author

Zoning

New York City is in a constant state of formal flux. The New York City Zoning Department has much to do with the speed and directions in which this formal change occurs. The Zoning Department decides where and how large buildings are in the city as well as what types of buildings, use groups, lot coverage, parking requirements, and FAR are permitted on each site(NY Dept. of City Planning). To facilitate a more realistic argument, Containment Building abides by the zoning codes and regulations assigned to the site.

The site, located just north of the Hudson River Rail Yard, is zoned as an M2-3 district. As part of the Hudson River Redevelopment Project, the Rail Yards themselves have recently been reassigned as C6-4 which indicates a city initiative to change the development of the area. The M2-3 districts are categorized as “medium-load industrial areas,” which, in addition to manufacturing and production, may include some commercial development such as businesses, government offices, and hotels(NY Dept. of City Planning).

Dimension and setback requirements for the M2-3 zone are as follows:

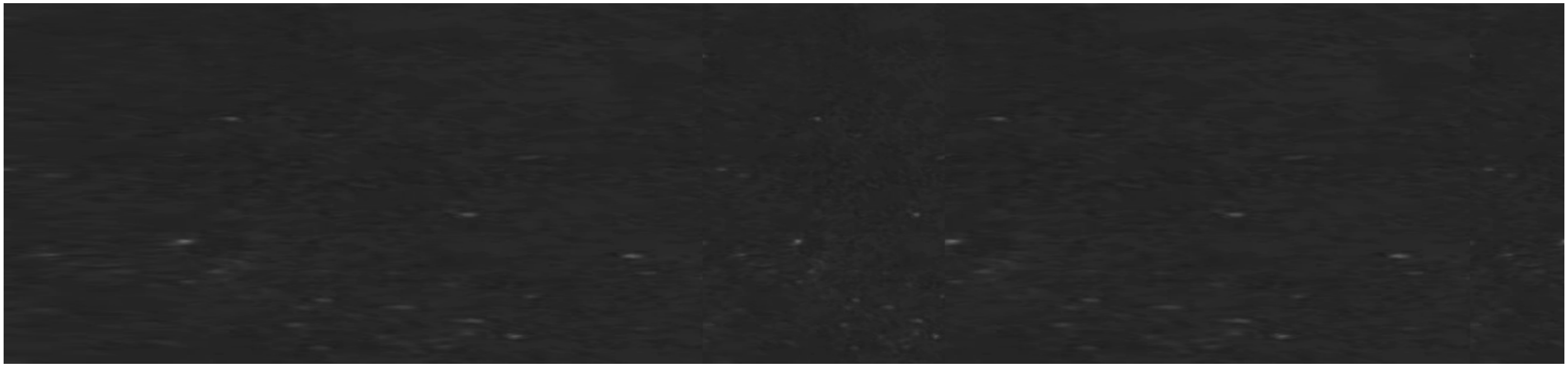
The M2-3 district allows a maximum FAR of 2 for manufacturing facilities and 2 for commercial facilities.

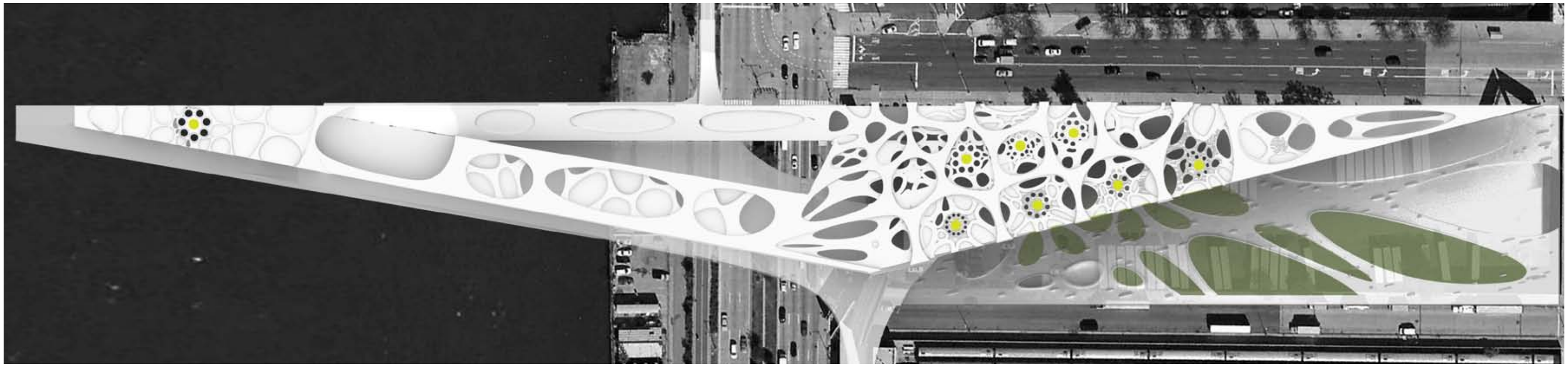
The wide street setback for the sky exposure plane is 10’.
Maximum street wall height: 66’.
Maximum building height: 88’v

Narrow street setback for sky exposure plane: 15’
The wide street setback for the sky exposure plane is 10’.
Maximum building height: 88’

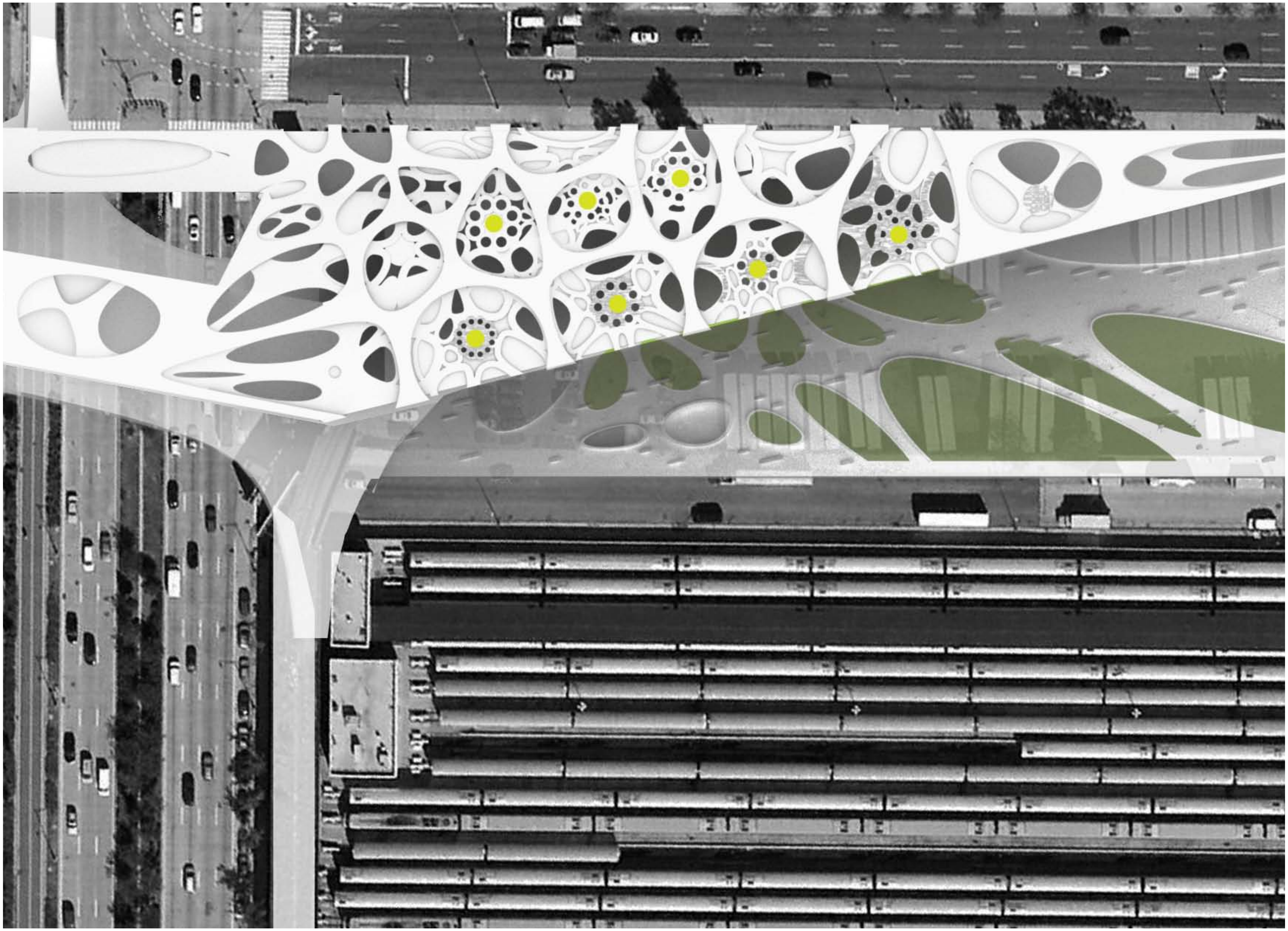
A building in the M2-3 district may attain a maximum height of 115’ on a wide street side and 100’ on a narrow street if the building is recessed 100’ from the respective streets.

(NY Dept. of City Planning)



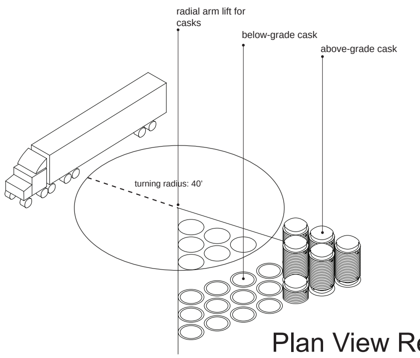


Plan View Rendering
image by author



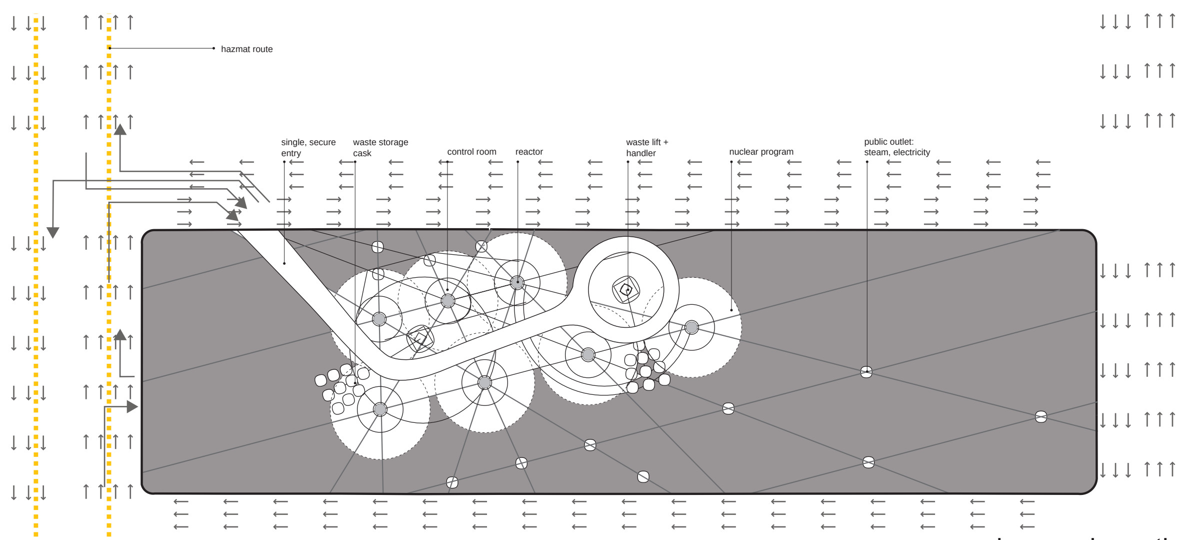
Access:
Trucking, fuel delivery, waste removal, and control rooms.

One of the primary considerations in siting a nuclear power plant is access. During plant construction, operation, and decommissioning, it is imperative that large vehicles and machinery can carry out their assigned tasks safely and effectively. As outlined in the New Criteria for Power Plant Siting, three main adjacency requirements are: 1.) access to federal hazardous waste transportation routes, 2.) proximity to train lines and 3.) federal waterways for ease of delivery of large equipment. Containment Building is located on the Hudson River, adjacent to the Hudson Rail Yards, and straddles the Joe DiMaggio Highway (New York Route 9A). Secure entry to the facility is attained through a single entrance on 34th Street, just a few meters from NY9A on the north eastern edge of the site. The single trucking entrance discreetly slips below the main public level of the facility which is flush with the eastern edge of the site. A guarded station at this entry strictly controls traffic in and out of the secure area below. The arrangement of the seven reactors is structured to allow delivery truck access, parking, and waste cask storage between them. Each reactor is protected by concentric arrangements of control rooms and support spaces such as offices, security, and parking buffer zones. Waste from the reactors is securely handled in the below-ground areas and stored in sealed concrete casks. The casks may be removed incrementally or stored on site until further space is needed. The trucking and service area also provides a dedicated zone for larger equipment and deliveries to enter the nuclear campus without disturbing the public zone above.



Plan View Rendering
image by author

Site Trucking and Access Strategies
images by author



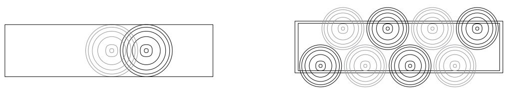
images by author

Perspective from Route 9A looking North image by author

Perspective from Route
9A looking North
image by author

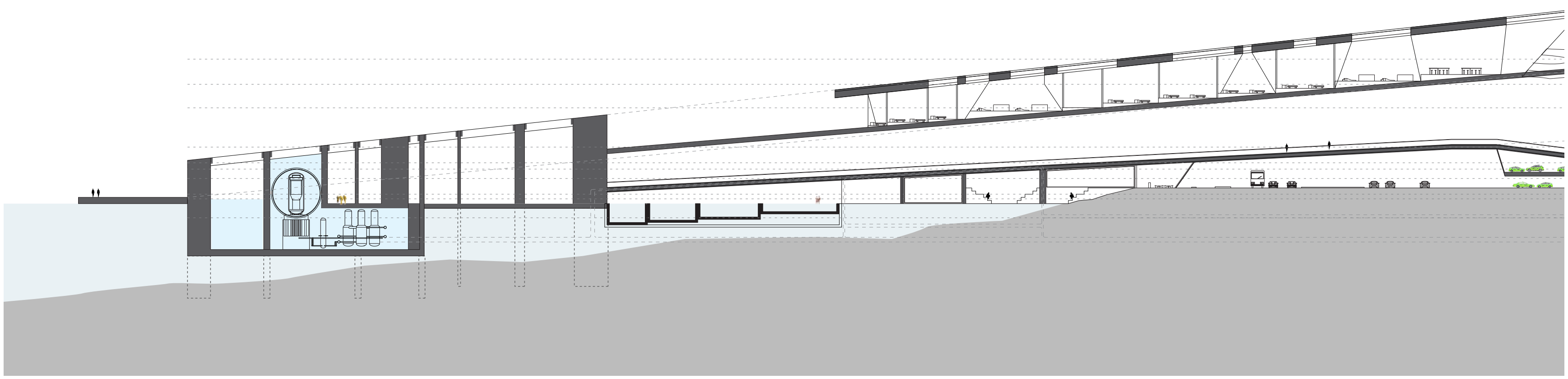
Sectional Strategy

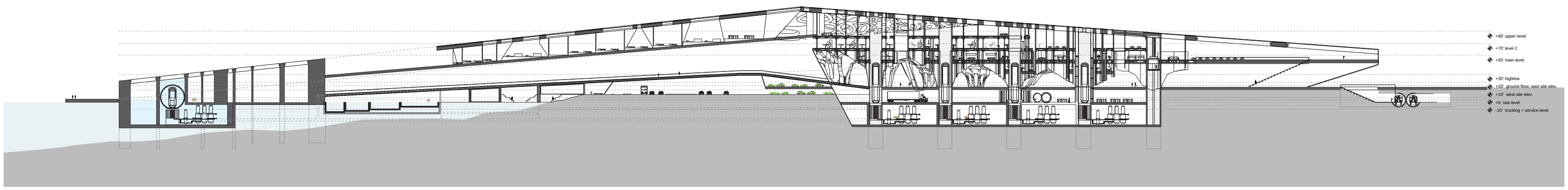
The eight reactors on the site are coupled to provide one fifth of New York City's total consumed energy. In determining the reactor model from the list of reactor models, the choice to produce an equal amount of electricity was between two larger reactors or eight smaller ones. Initial diagrammatic explorations investigated the benefits of either arrangement relative to programmatic access to the reactors as well as space on the site. In the two reactor approach, the footprint of each reactor was larger, but access to the reactors was limited. In the eight reactor test, by testing similar concentric arrangements, much more linear space could be extracted from the eight reactors than from just the two. Essentially, by breaking the production of electricity into a number of smaller pieces, more nuclear-reliant programs such as nuclear medicine, nuclear imaging, and food irradiation could be arranged around the reactors themselves. This in turn, would not only benefit the nuclear programs, but separate the reactors from the public through a series of bundled programs.



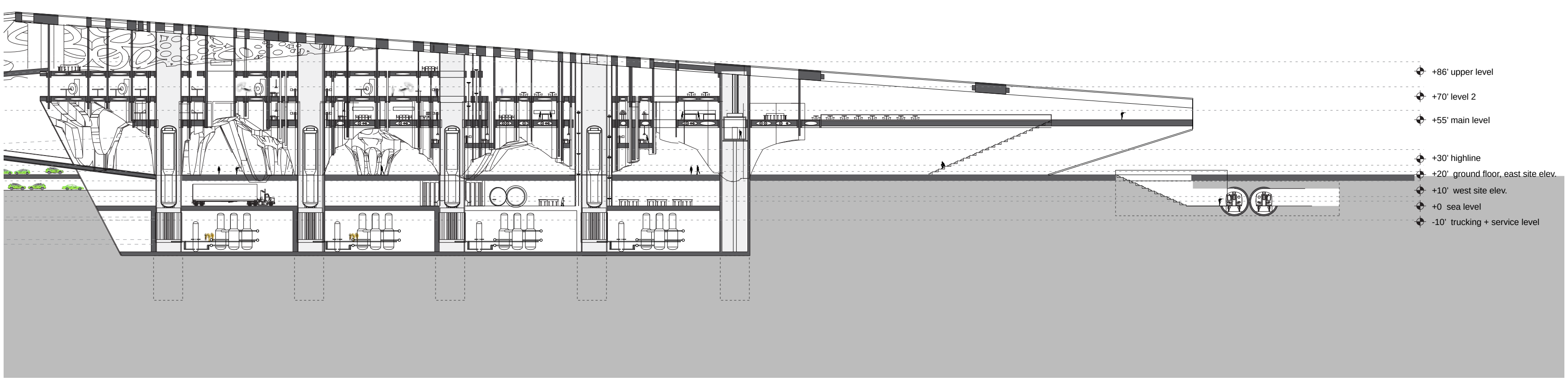
reactor placement diagrams
images by author

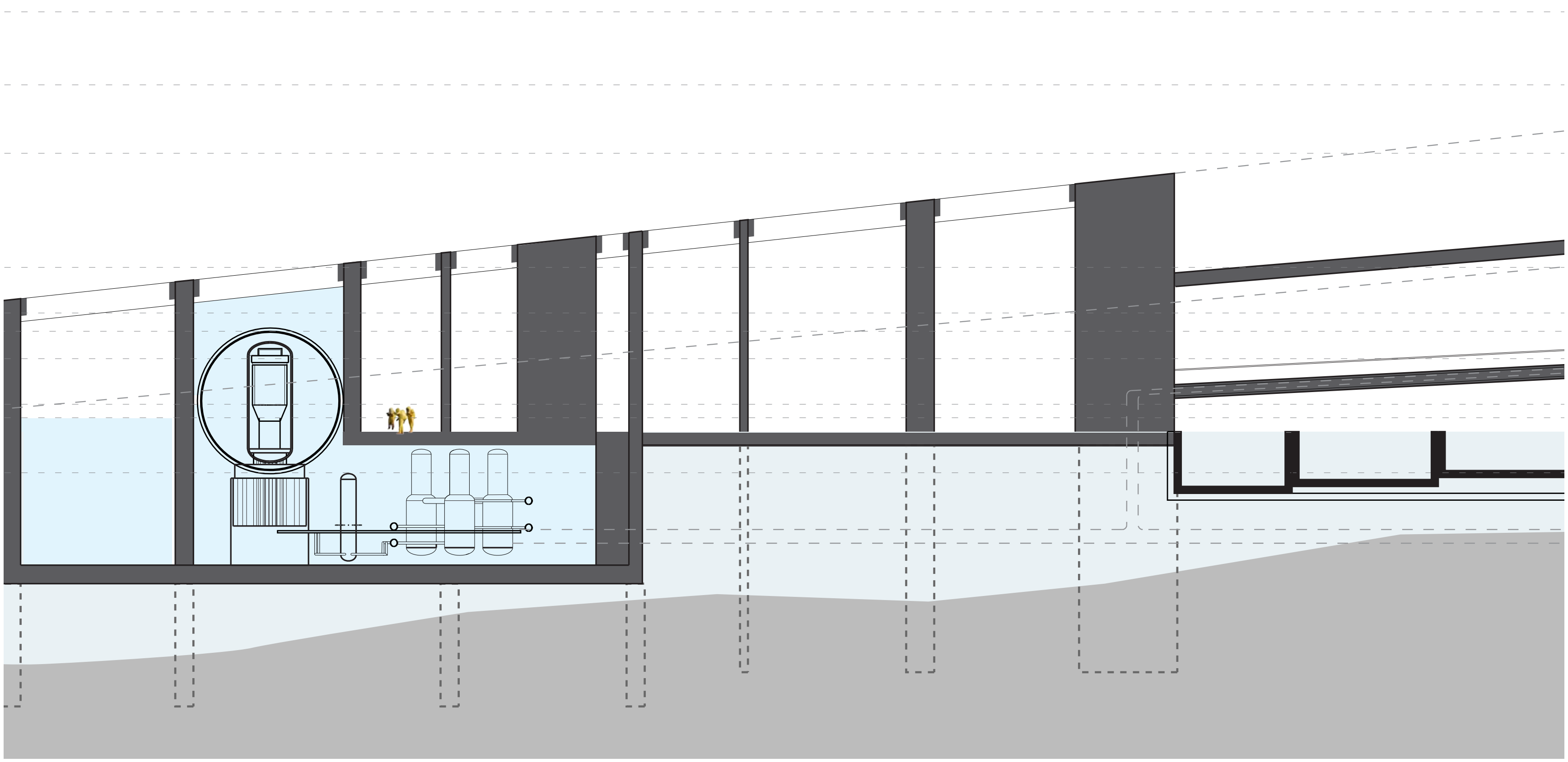
Containment Building is organized around an extremely active section. On the broader scale, the elevational shift between the western and eastern extremities of the site allows west-access programs to slip below the main public way. As the building slopes up and down from west to east, the ground below maintains a datum where the operational and mechanical activities take place. The bundling of programmatic tubes around the reactors in plan, when cut orthographically, produces a striated section which forms the outer edge of the building. The interior public spaces, in contrast, are cut more organically. Inverted, tapering cones carve excess tubes from the bundle to allow large, vaulted spaces to span over the grand hall. Additionally, as the bundles are thinned, large volumes of light are permitted to enter the innermost section of the building.





Building Section Looking North
images by author





Building Section Looking North
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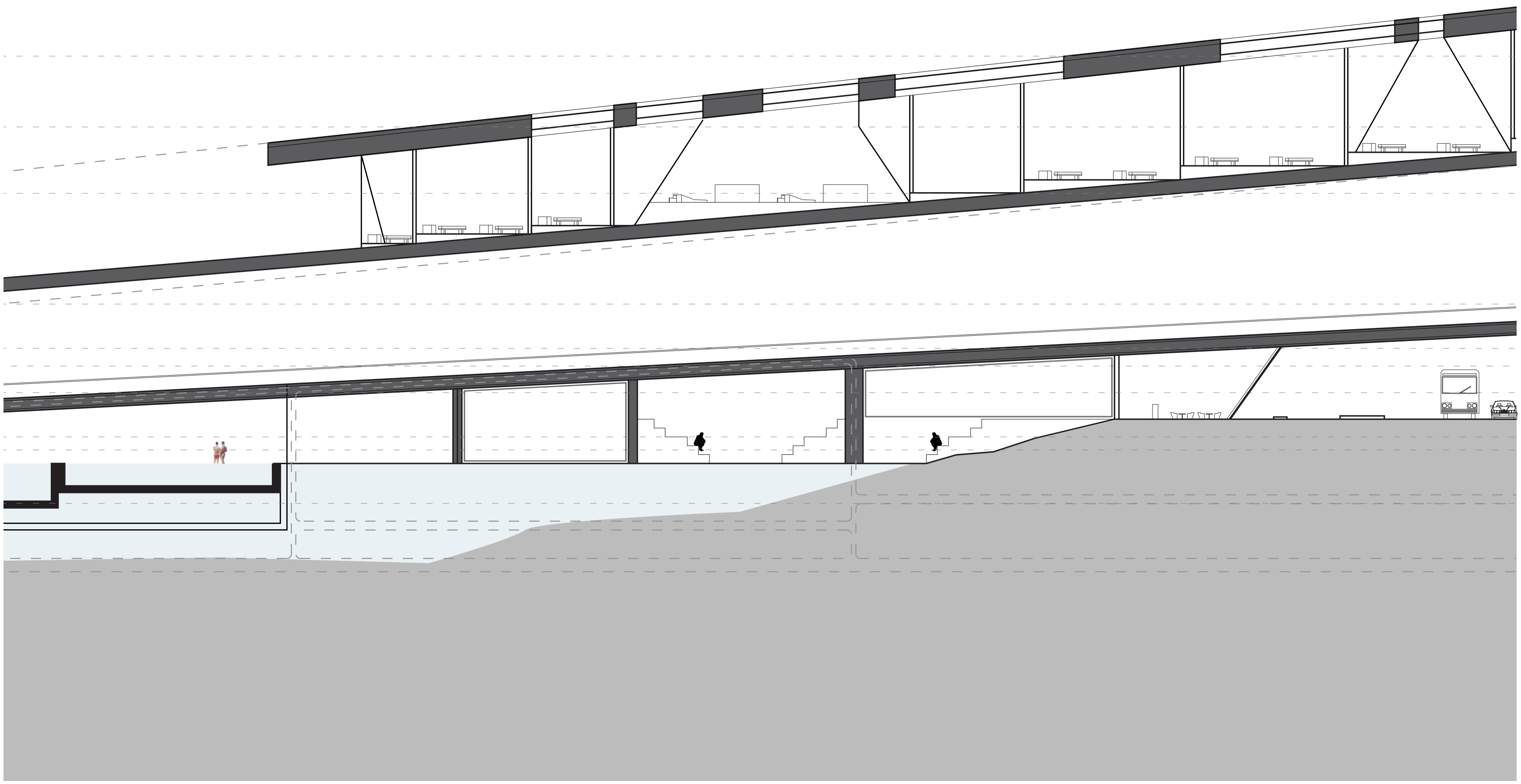
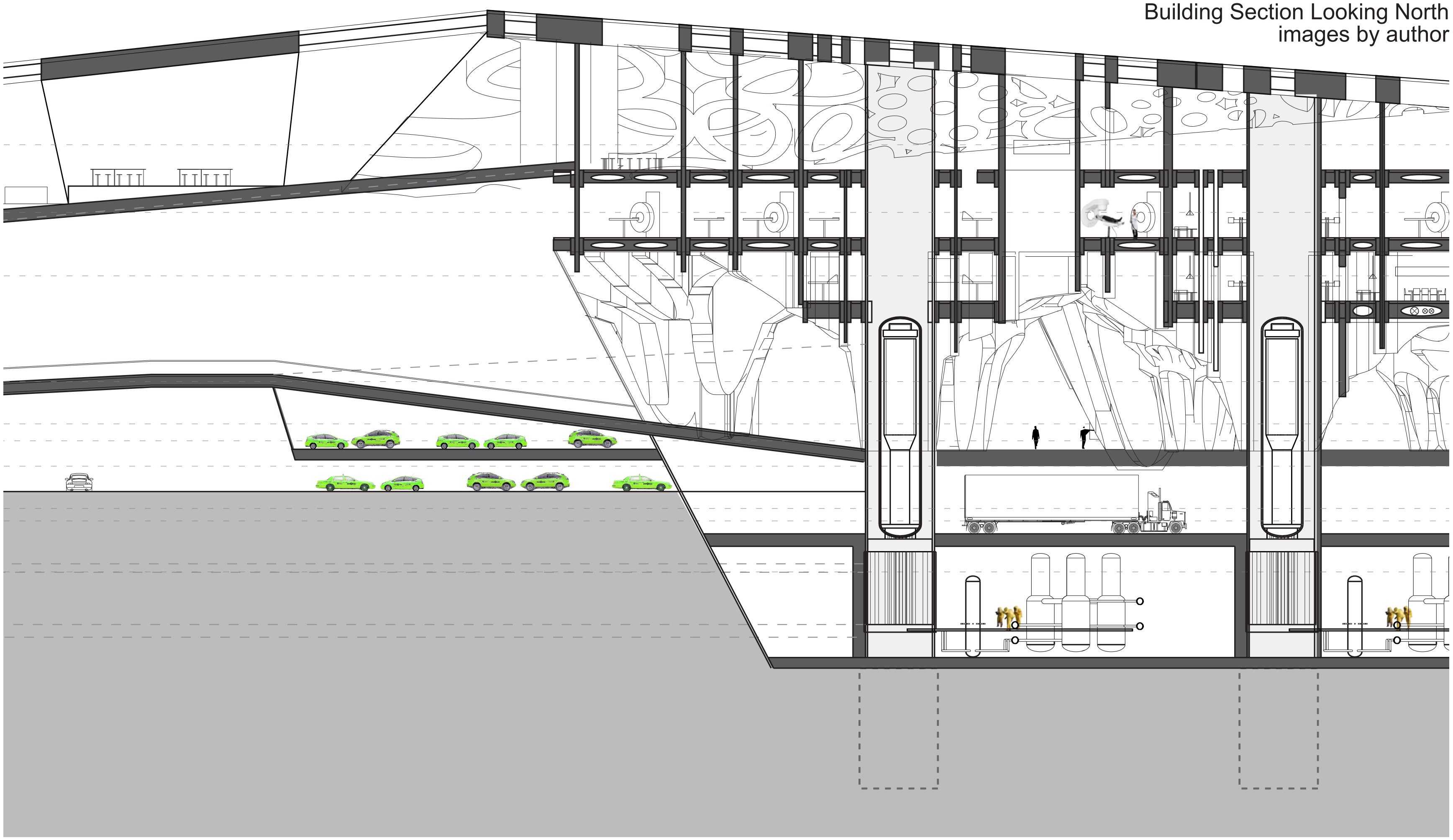
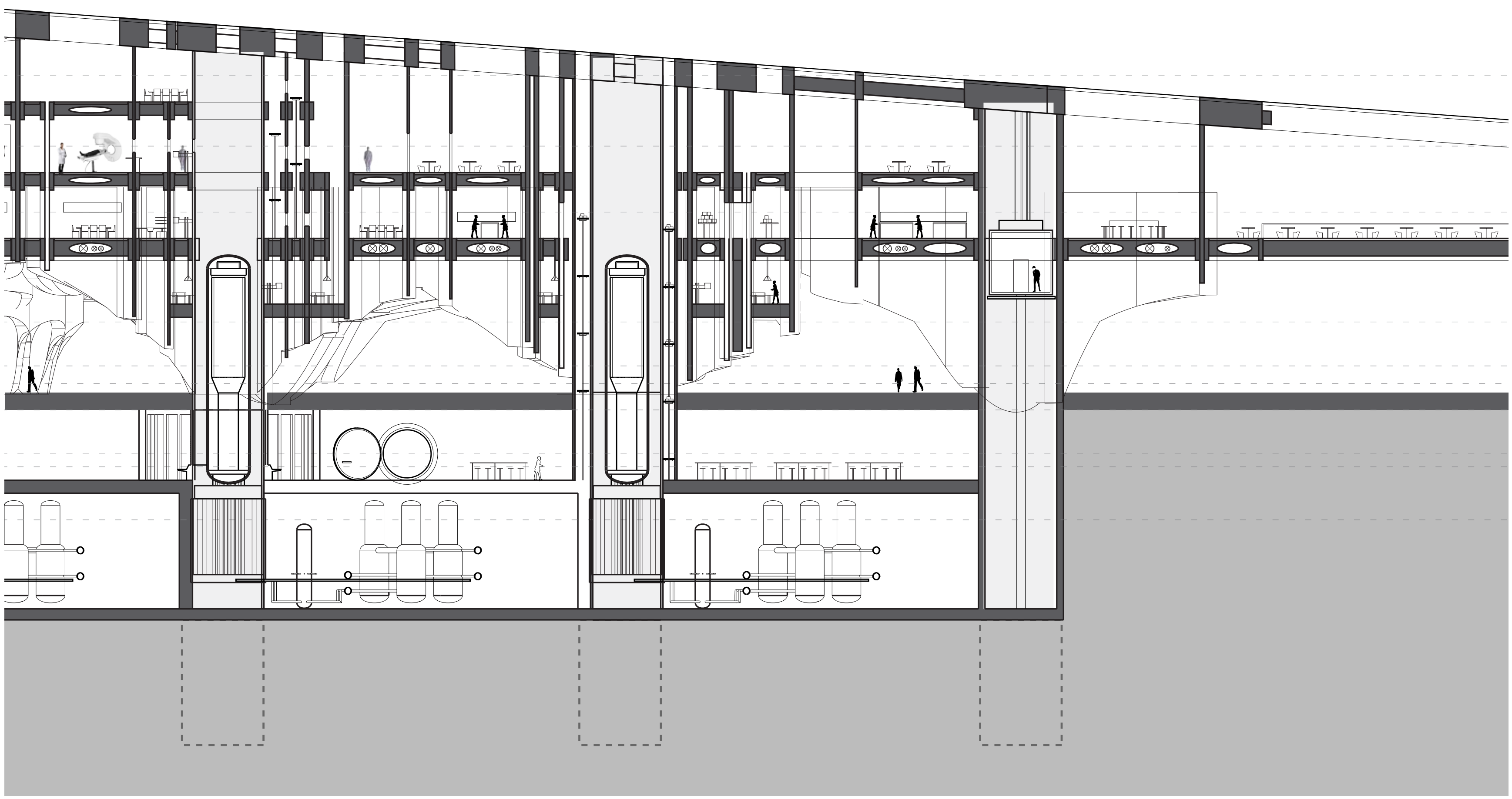
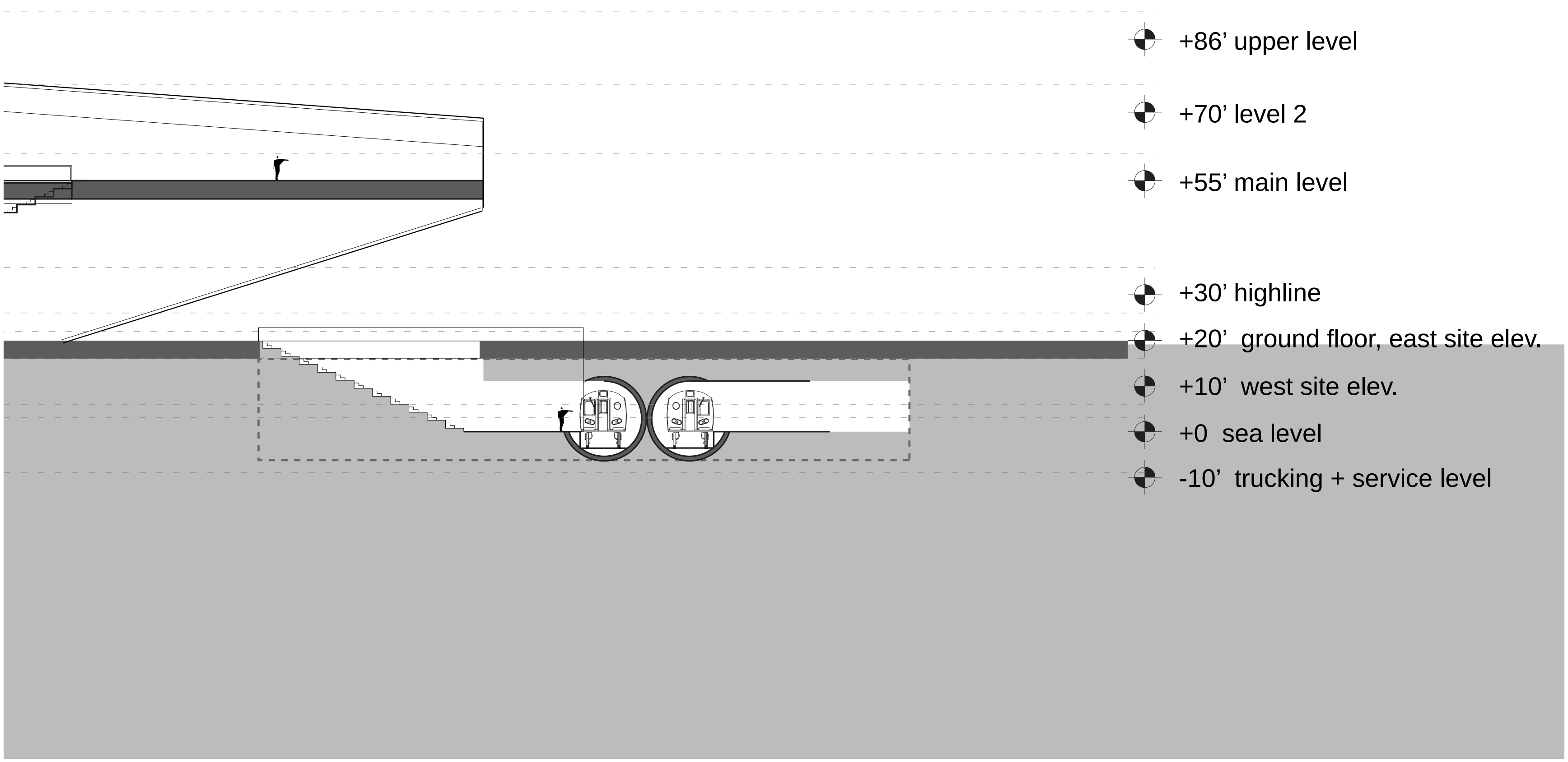


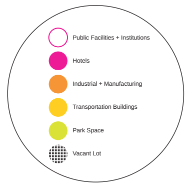
Building Section Looking North
images by author





Building Section Looking North
images by author





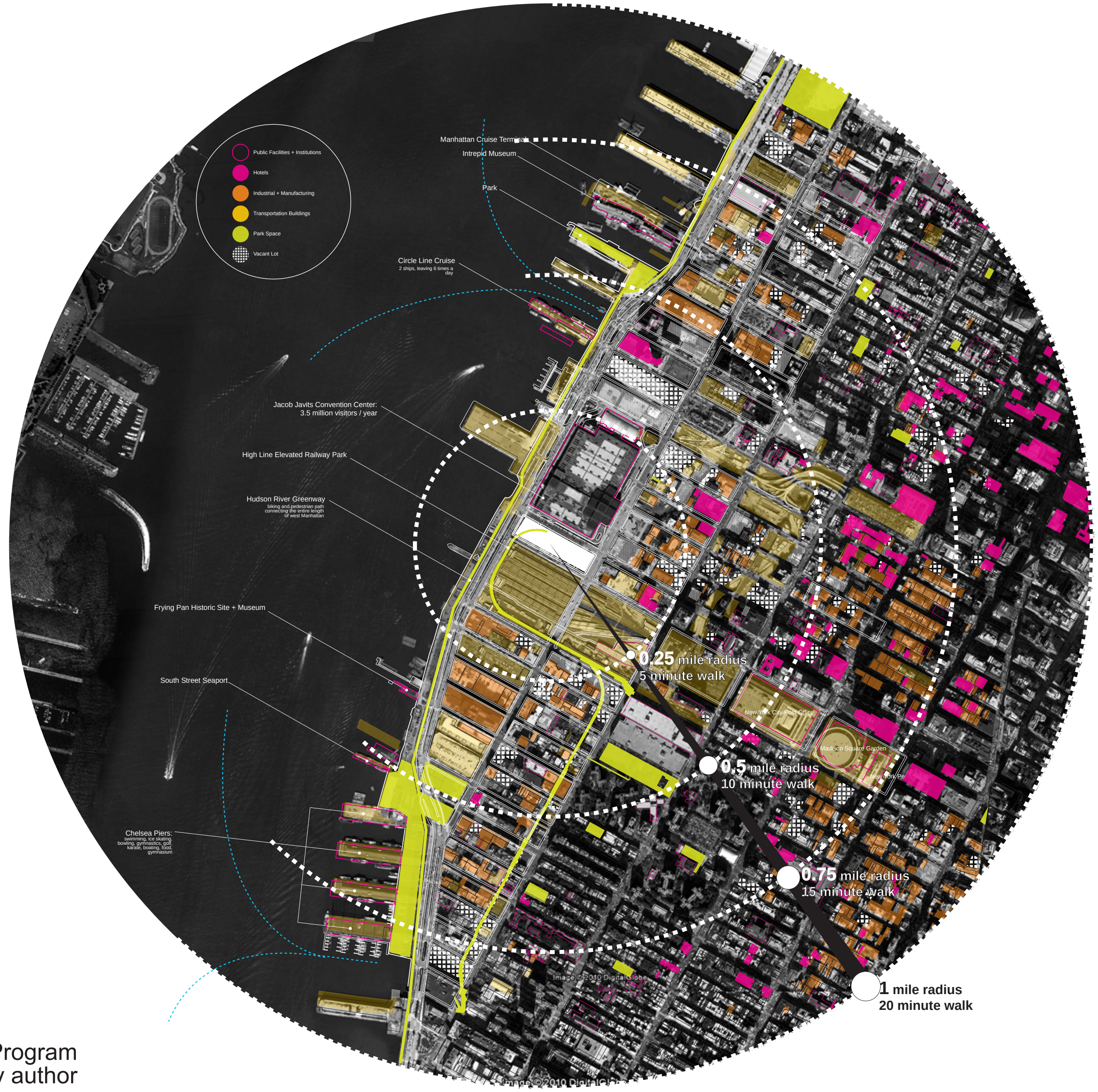
Site Analysis of Local Program
image by author

Program:

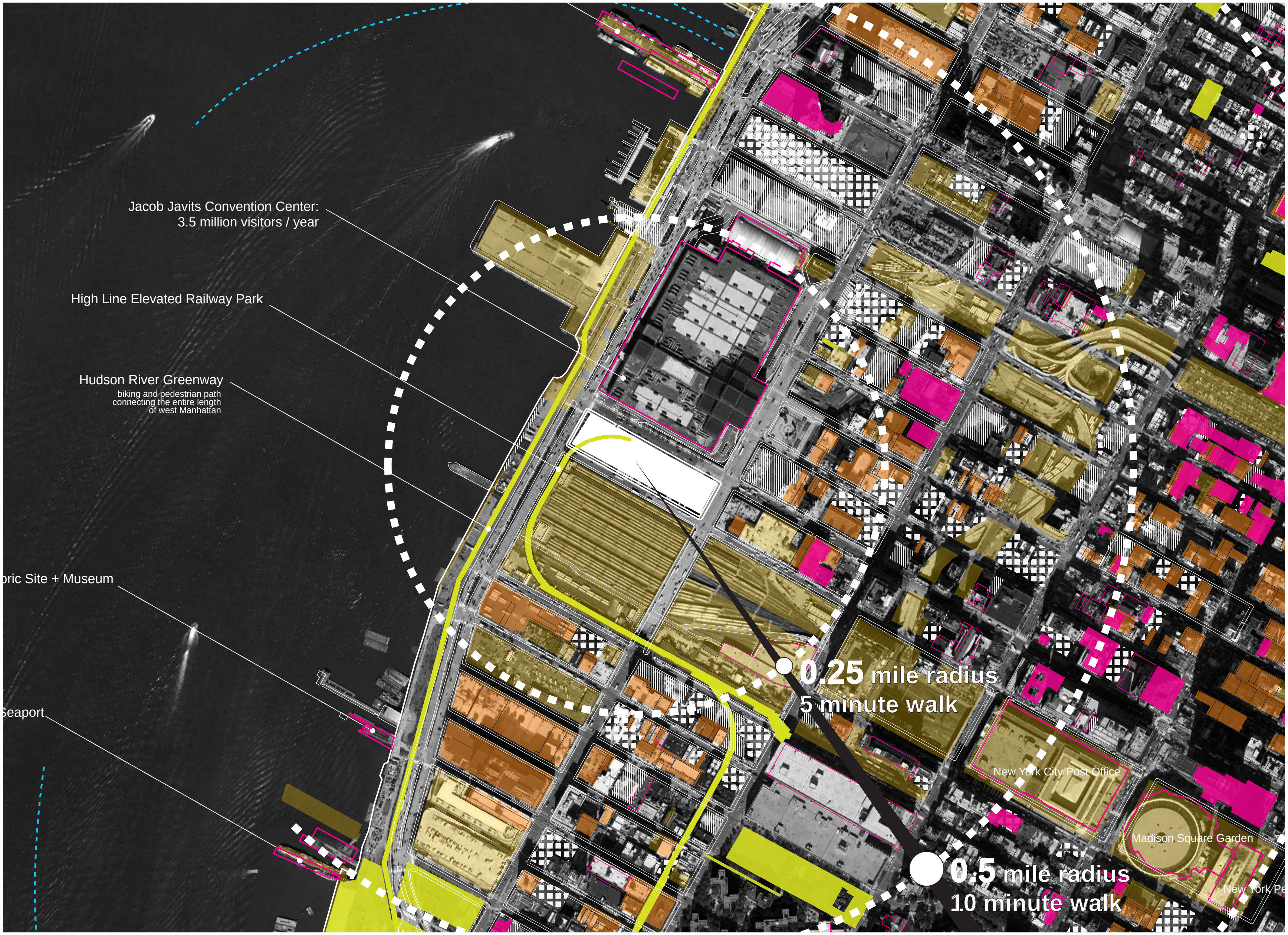
The core of the project is a series of LFTR reactors that supply one fifth of New York City's total consumed power. The layers that encase this project are filled with radiation-using, heat-absorbing, and power-consuming programs. the Containment Building. Containment Building's nuclear campus is composed of a series of interrelated programs that promote the use and advantages of nuclear science and technology. Coupling Geographic Information System (GIS) mapping and contextual site data, I analyzed the categories of existing program on the site and their proximity relative to pedestrian walking distances. The mapping uncovered a series of patterns in development as well as a number of voids in supporting program. For example, there are a large number of tourist attractions along the West Side Highway including the Intrepid Museum, Circle Line Cruises, the Manhattan Cruise Terminal, the Highline Elevated Park, and the Jacob Javits Convention Center. Many of these attractions are connected by the Hudson River Greenway (a landscaped bike and pedestrian path along route 9A) but the busy highway separates them from the rest of the city. Additionally, a number of industrial, manufacturing, and transportation buildings surround these attractions, proving difficult to traverse 10th through 12th Avenues comfortably. Also lacking are public transportation connections, a park, restaurants or bars, and hotels. Based on this analysis, I chose a series of nuclear programs that filled the contextual programmatic gaps while facilitating nuclear wellness and technology.

In addition to the nuclear power plant, the assigned programs include: a nuclear medicine and imaging center, a food irradiation facility, nuclear testing labs, a wellness hotel and spa, a public bath house, a bar, restaurant, electric taxi charging station, and a Plug-in Park. As there is no single facility with the above program, precedents of the above programs in dedicated arrangements were cataloged in terms of adjacency, room and program dimensions, service requirements, and overall scale. I assigned program requirements based on these precedents.

view from 11th Ave. and 34th St. looking west
image by author



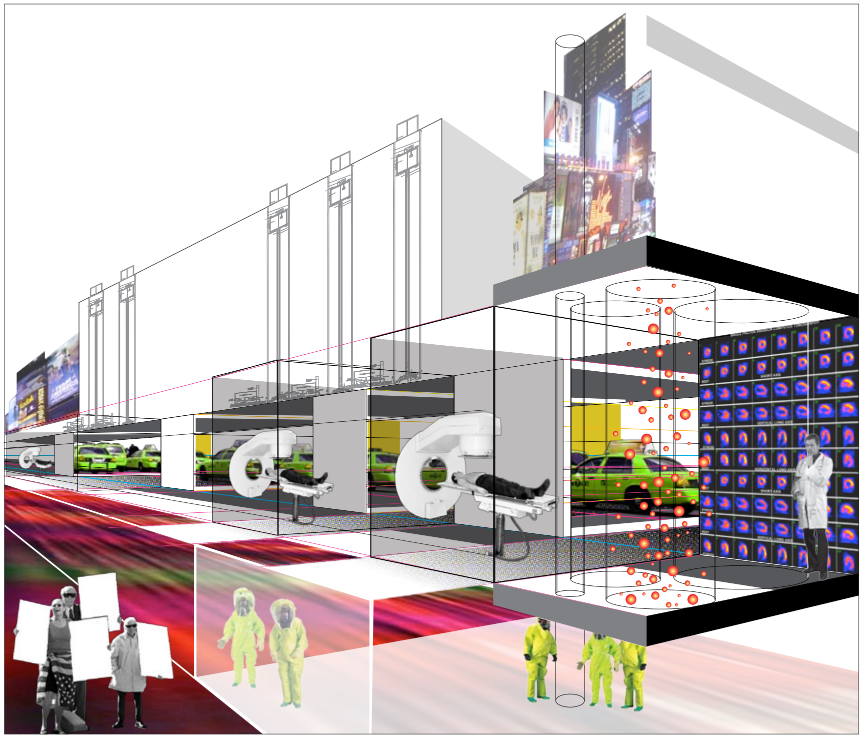
Site Analysis of Local Program
image by author



Jacob Javits Convention Center:
3.5 million visitors / year
High Line Elevated Railway Park
Hudson River Greenway
biking and pedestrian path
connecting the entire length
of west Manhattan
oric Site + Museum
Seaport
0.25 mile radius
5 minute walk
New York City Post Office
Madison Square Garden
0.5 mile radius
10 minute walk

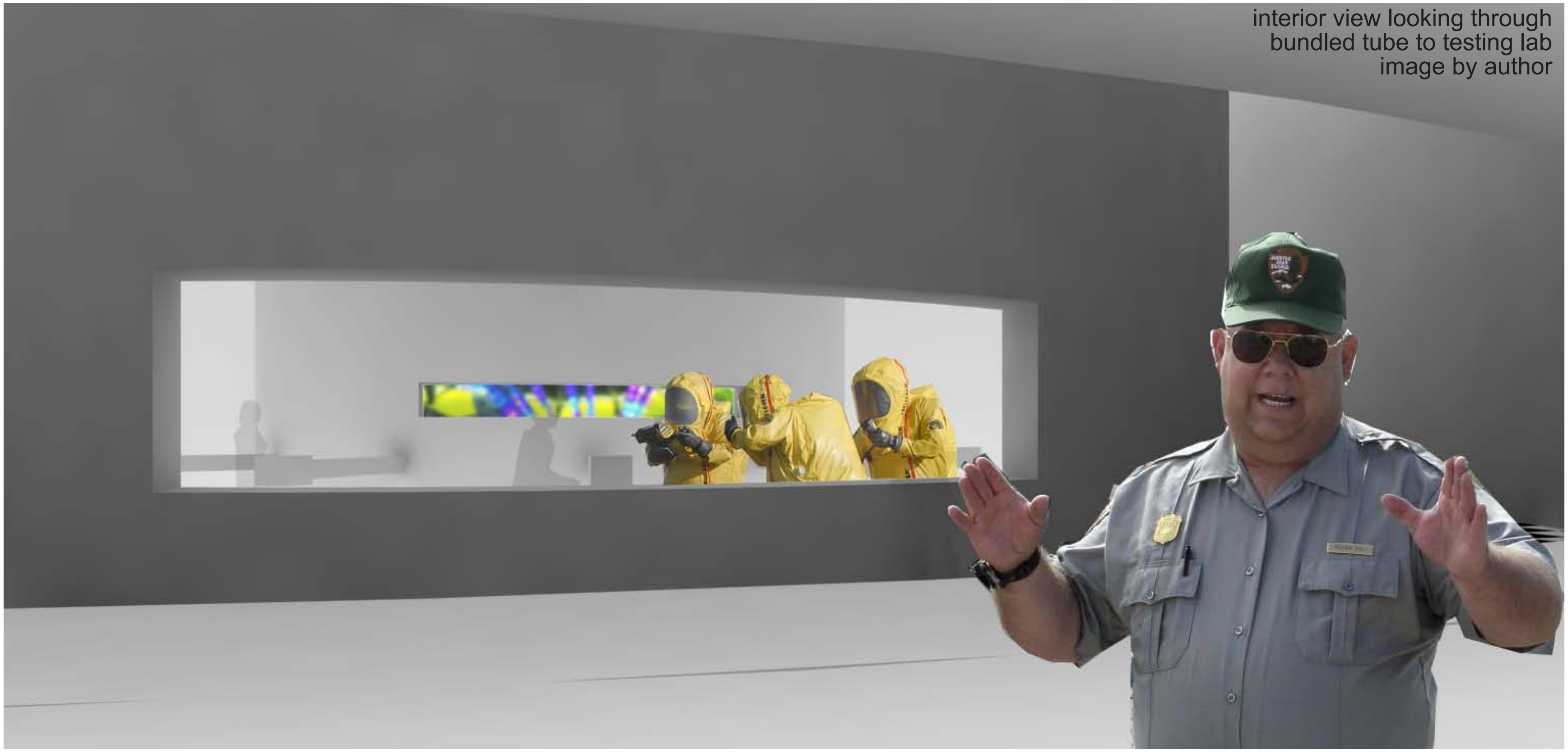
Nuclear Medicine Facility + Imaging Labs

Nuclear medicine is defined as "a branch or specialty of medicine and medical imaging that uses radionuclides and relies on the process of radioactive decay in the diagnosis and treatment of disease("Nuclear Medicine)." Most major hospitals have a nuclear medicine department, but there are few dedicated facilities. By integrating a dedicated nuclear medicine facility into the building, patients, doctors and researchers will have the opportunity to exchange goods, information, and services safely and beneficially through the building. The placement of the reactors in the midst of the programmatic cores ensures that the materials exchanged and radiation extracted are secured for the intended users. Vertical exchanges are facilitated through the vertical connections around the cores. Medical waste, materials, and medicine have dedicated passages that connect labs and services throughout the section of the building.



Conceptual Rendering of Programmatic Adjacencies image by author

Major operations for the nuclear medicine facility are: patient access, programmed adjacency, treatment rooms of varying service and patient duration, mechanical equipment and machine placement, medical waste handling, and pharmaceutical dispersion. Patients are dropped off at the north-west corner of the site at the dedicated medical drop-off. The ground floor lobby and registration greats and organizes patients. Once admitted, patients are escorted to the main medical level. The medical level is organized by nuclear / radiological necessity. Smaller nuclear testing rooms, radioisotope labs, and medical waste and material transfer departments directly surround the reactor cores. The arrangement is modeled on a tight-pack system where volatile activities and materials are secured together around the cores and as the adjacency to radiation is less pertinent to the medical facility activities, those programs are placed further away from the cores. Varying scales of treatment rooms reflect patient stay duration and degree of treatment. The facility is divided into two main divisions of nuclear medicine: imaging and treatment. In the imaging department, patients are given (either orally or intravenously) radiopharmaceuticals. As the radiopharmaceuticals travel through the body, the machines can image the disease in the body("Nuclear Medicine"). A patient undergoing nuclear treatment is administered radiopharmaceuticals that target the diseased area. When exposed to the machine-generated radiation, the chemical compounds attack the target area. The mechanical space for the



interior view looking through
bundled tube to testing lab
image by author

radiation machines occupy over 100 linear feet of space and therefore are a major organizing component of the facility. The patients may stay at the nuclear medicine center for anywhere from 30 minutes to a few days. The center is therefore connected to a wellness hotel and spa to speed recovery and improve on patient well-being.

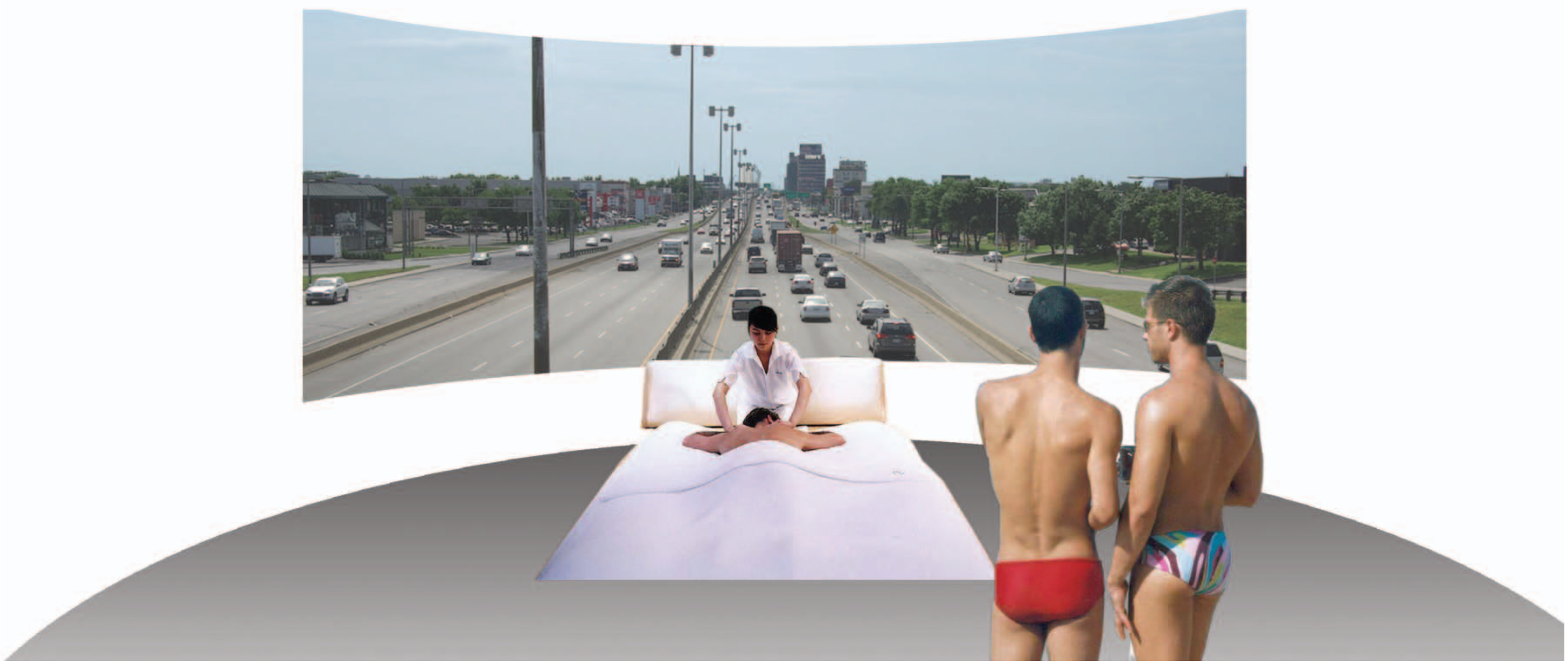
Nuclear Testing Labs

Modeled after the experimental reactor lab at the Massachusetts Institute of Technology, the testing labs surround three of the reactor cores. The testing involves exposing materials and processes to radiation to test their performance. This is achieved through a radial arrangement of “spokes” that divert beams from the reactor core into contained vessels branching out from the center. The labs are open to universities and to scientists working on the nuclear campus. The testing labs facilitate nuclear research in the city while being linked to the nuclear campus above(see page 120).

Food Irradiation Facility

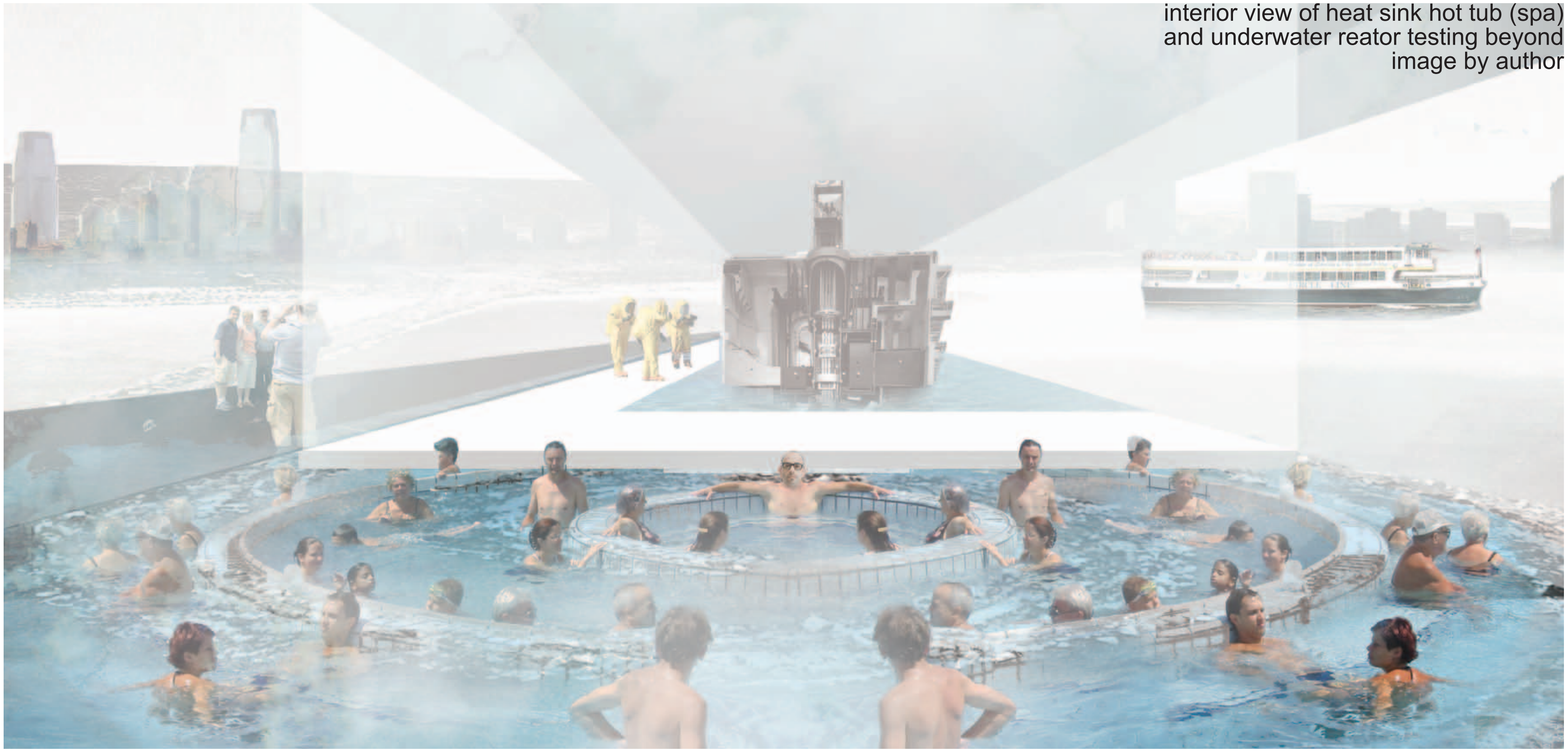
All of the programs in the nuclear campus are composed to attract a public, utilize direct access to radiation, and promote wellness through the above combined intentions. The food irradiation facility provides clean, safe food to New York buyers as well as the users of the nuclear campus facilities. Food irradiation is a process of “exposing food to ionizing radiation to

interior view of wellness hotel
room overlooking route 9A
image by author



destroy microorganisms, bacteria, viruses, or insects that might be present in the food;"("Food Irradiation") the nuclear campus restaurant, hotel cafeteria, and hotel restaurant all use the food irradiated in this facility to promote the nuclear program and wellness. Trucks make pickups and deliveries to the food irradiation lab through the trucking and services access below. Visitors may indulge in the bacteria-free food in the park via a take-out counter in the main hall or in the restaurant cantilevering over the campus entrance. The food will be an attractor to the campus and the dispersed products will further attract visitors to the facility.

Major operational components for the food irradiation facility are food delivery, irradiation machinery, food storage, processing, offices, packaging, and dispersion. The primary activities occur on the below-grade level. Food is delivered for treatment via the service entrance and sent out for delivery by the same method. Food is moved by conveyors into exposure rooms surrounding the reactors. The treated, bacteria and insect-free food is then ready for packaging and dispersion. Much of the food is kept on site to supply the restaurant and bar above, the medical cafeteria, and the sidewalk cafe at ground level. The rest of the food is packaged for delivery throughout the city. for packaging and dispersion. Much of the food is kept on site to supply the restaurant and bar above, the medical cafeteria, and the sidewalk cafe at ground level. The rest of the food is packaged for delivery throughout the city.



interior view of heat sink hot tub (spa)
and underwater reactor testing beyond
image by author

Wellness Hotel + Spa

The wellness hotel and spa are integral to the operation of the nuclear medicine facility. Patients who need relief and a place to stay after receiving treatment may stay in the wellness hotel or relax in the spa. The hotel and spa rely on heat and steam produced by the underwater reactor to power the wellness rooms. Saunas, hot tubs, and steam rooms relieve the heat loads from the reactor while supplying the guests with super-heated amenities. The heated programs are essentially programmatic cooling ponds, mitigating the heat between the reactor and the environment. Guests are welcome to stay at the wellness hotel and spa even if they are not patients at the hospital to indulge in the benefits of nuclear wellness.

Public Bath House

The public bath house is located to the west along the Hudson River Parkway, below the pedestrian park and overpass. Health enthusiasts can break from the bike and running paths for a shower and sauna. The bath house is directly adjacent to the underwater reactor laboratory, siphoning heat from the reactor into concentric cooling ponds that double as hot tubs for spa guests. The bath house is an insertion along the active corridor that programmatically extends the activities of Chelsea Piers north along the highway.

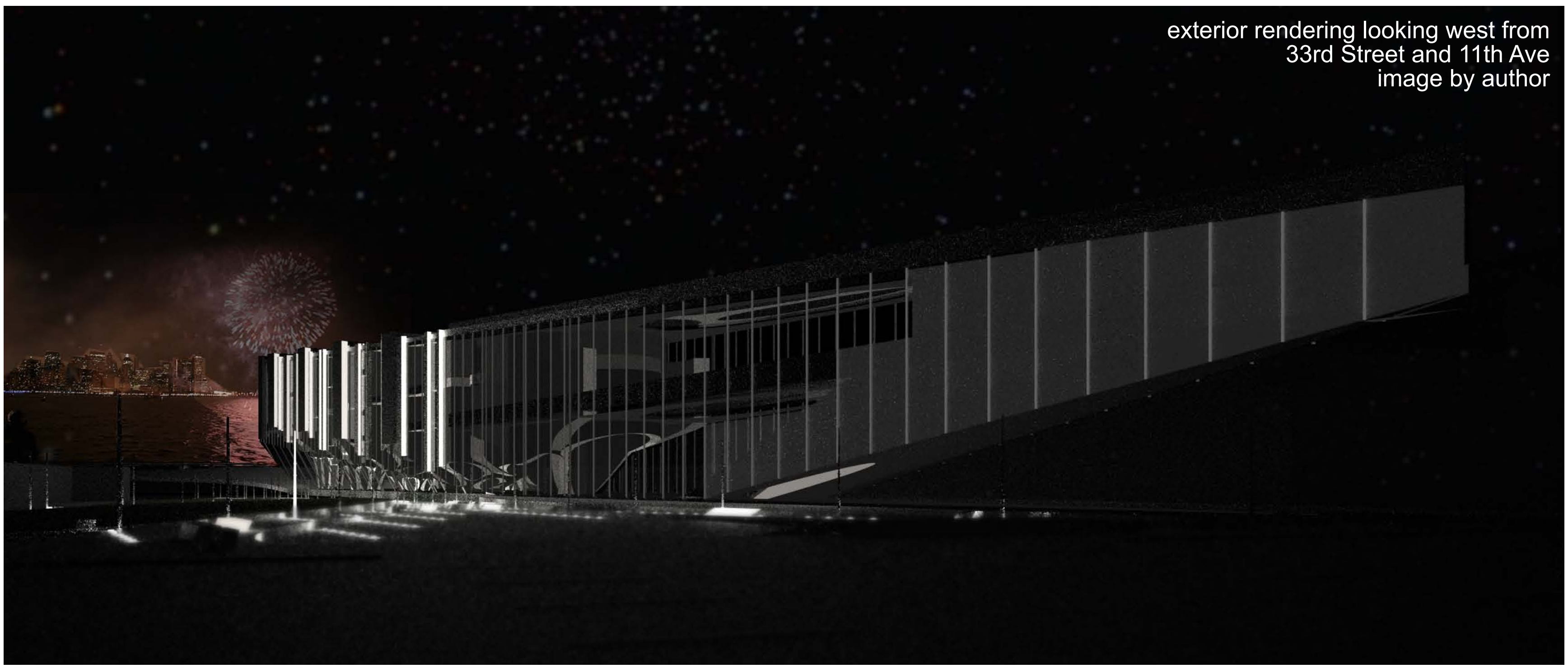
Electric Taxi Charging station
The sole non-nuclear-specific program in the project is the electric charging station. Transportation is the second largest electricity consumer in New York City, so the charging station anchors the hub for real initiatives to change the New York City taxi system into an all-electric fleet(Ascher). The charging stations proximity to the on-site electricity generation advantageously reduces some of the need for electric transport infrastructures. Taxis enter the charging station from the West Side Highway (route 9A) entrance onto the site. Three levels of parking-charging stations are tucked below the main hall level. The site has a capacity to charge 200 taxis at any given time. As the city transitions into the all-electric fleet, the electric taxis are marked by a chartreuse paint job. As the fleet disperses into the city, it informs the pubic of the new, electric taxi era. In addition to the subway station, the electric charging station is one of two programs that do not rely on nuclear-specific energy production, but rather concentrate on the connection between a highly consuming electric program with a massive, transit-needing public.

Plug-in Park
A direct circulation path connects the end of the Highline at the south-western corner of the site to the new subway stop at the north-eastern corner of the site, bisecting the city block between 33rd and 44th Streets along the hypotenuse. The Plug-in Park occupies the southern half of this division. The large public area is activated by a series of paths around planted petals. Some are the larger shapes within the park are paved, opening the possibility of a wide variety of activities to occur in the open. The horizontal petals register the change in elevation across the sloping paths of the site. Two petals towards the south of the site are programmed cooling ponds connected to the infrastructure of the under-

exterior rendering looking west from
33rd Street and 11th Ave
image by author

water reactor lab to the west. The cooling ponds maintain a constant temperature year-round, steaming in the winter months and cooling in the heat of the summer. Urbanistically, the park offers relief to the massive structure to the north, allowing southern light to enter the building unobstructed. The open space also recognizes the potential development to the south (the proposed site for the Olympic Stadium) and secures the landscape surrounding the nuclear complex.

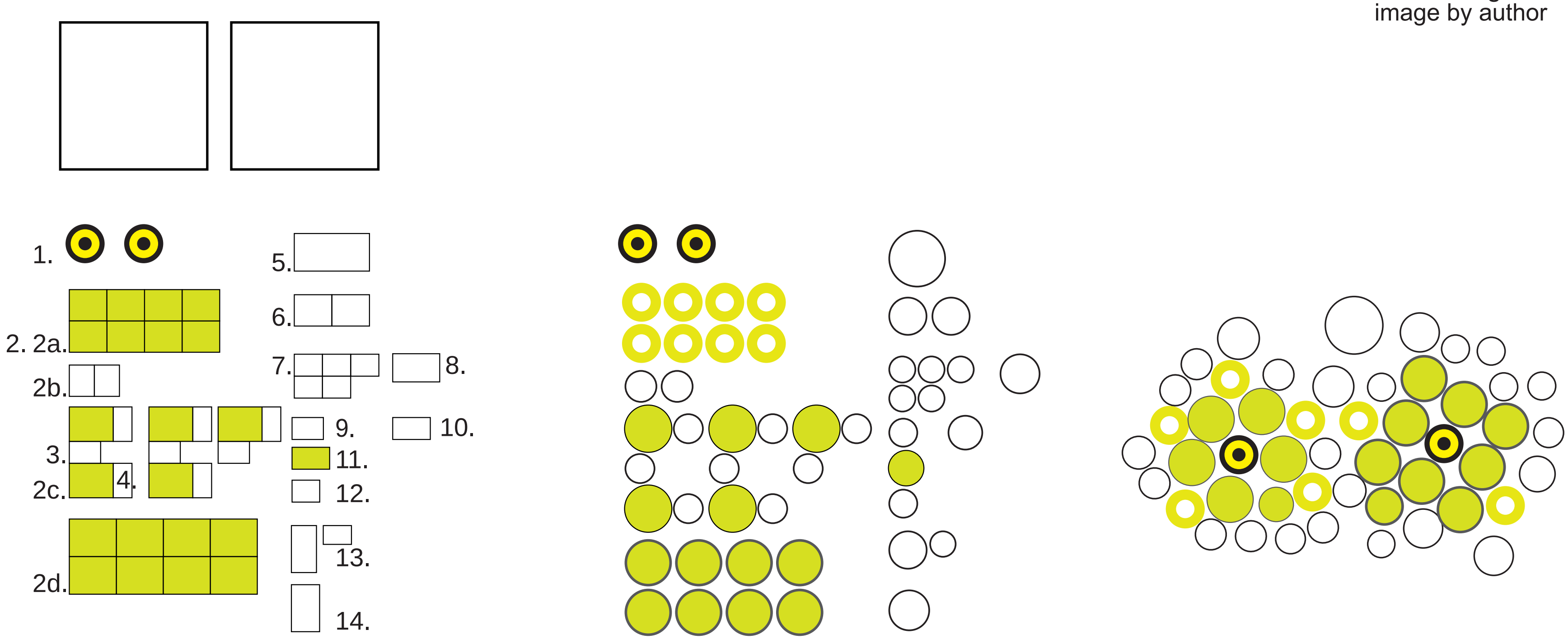
The Plug-in park is active both day and night. The park is populated with electric outlet-equipped benches and outlet-covered light poles. The tangle of pipelines and cables below blossom in the park and offer free services to the public. including electricity, steam, and light. Day and night, visitors can enter the electrified wonderland and reap the resources of nuclear power. During the day, visitors to the nuclear campus populate the park grounds as they traverse the site between the subway stop and the Highline. The active public can easily break from the west side highway pedestrian paths and either enter the waterside park and pier or cross the pedestrian bridge to meet the Highline or the plug-in park. Tourists and business people alike will flock to the park for spectacle and repose. Conveniently adjacent to the Jacob Javits Convention Center, convention-goers will be able to come to the new electric park for a quick charge or for a treat from one of the many electric or heat-consuming vendors. The light poles ensure safety and a glowing ambiance late into the night, giving life to the connected Highline which transitions into a glowing, electric spectacle.



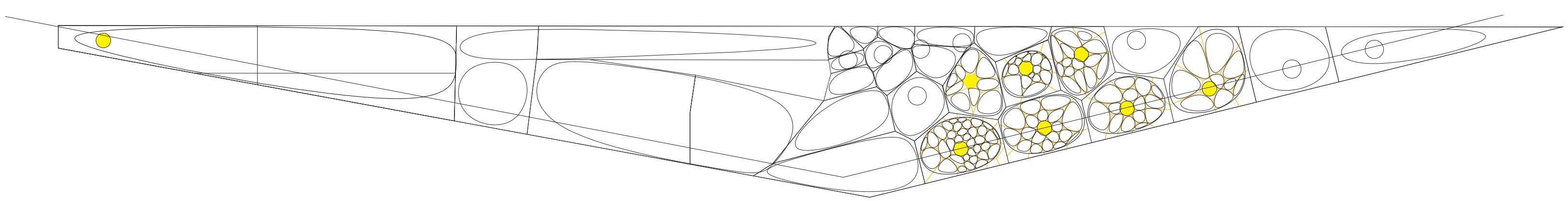
exterior rendering looking west from
33rd Street and 11th Ave
image by author

Nuclear Medicine
20,000 sq ft

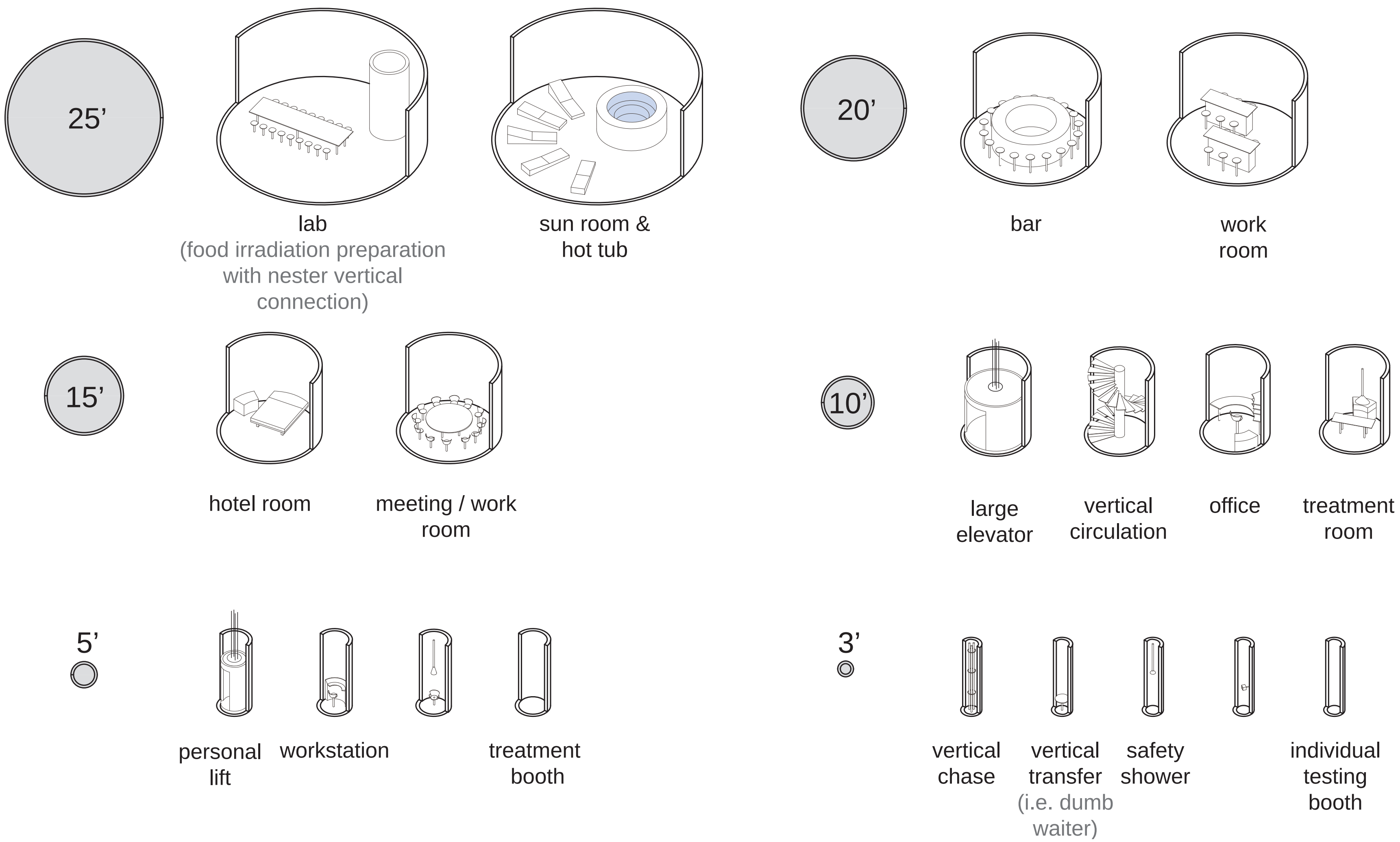
Diagram of Program Analysis:
Precedent Program Study to Reactor-Centered Bundled Program
image by author



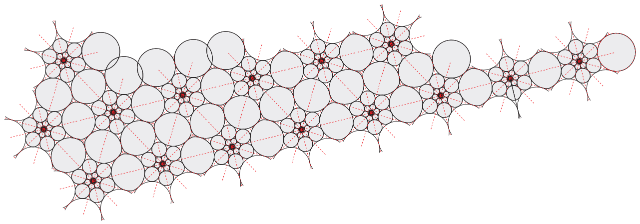
Surveyed Programs:
1. Reactors
2. In-Patient Rooms:
2a. Group 1 20 min: 8
2b. Group 2: 10min: 2
2c. Group 3: 35 min: 5
2d. Group IV: 120min:8
3. Control room
4. Dressing room
5. Waiting room
6. Consultation room: 2
7. Office: 5
8. Conference
9. Scrub area
10. Monitor
11. Hot lab
12. Preparation
13. Dark room
14. File + film storage



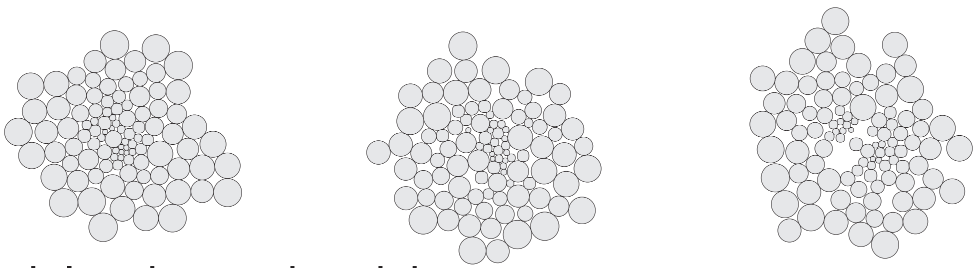
Dimensionally Organized Program
image by author



Programmatic Bundling amd Carving
image by author



bi-lateral symmetrical pack



circle pack: constraint variations

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max radius: 30'
fast pack: yes
contract: yes

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fast pack: no
contract: n/a

min radius: 5'
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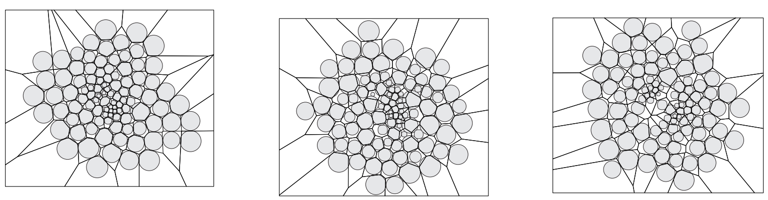
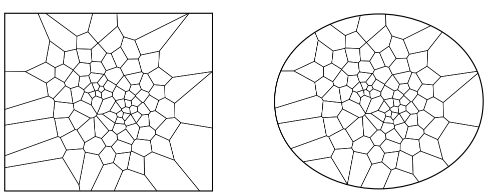
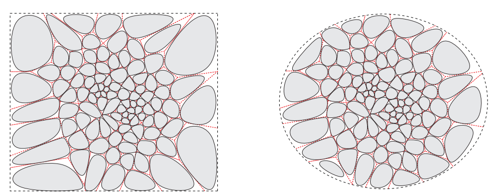


circle pack-informed voronoi

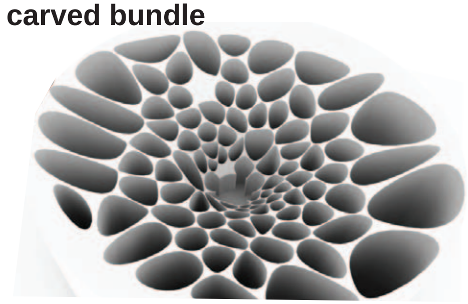


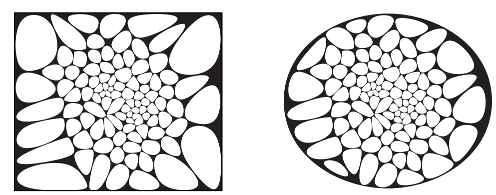
circle pack-informed voronoi variable boundary



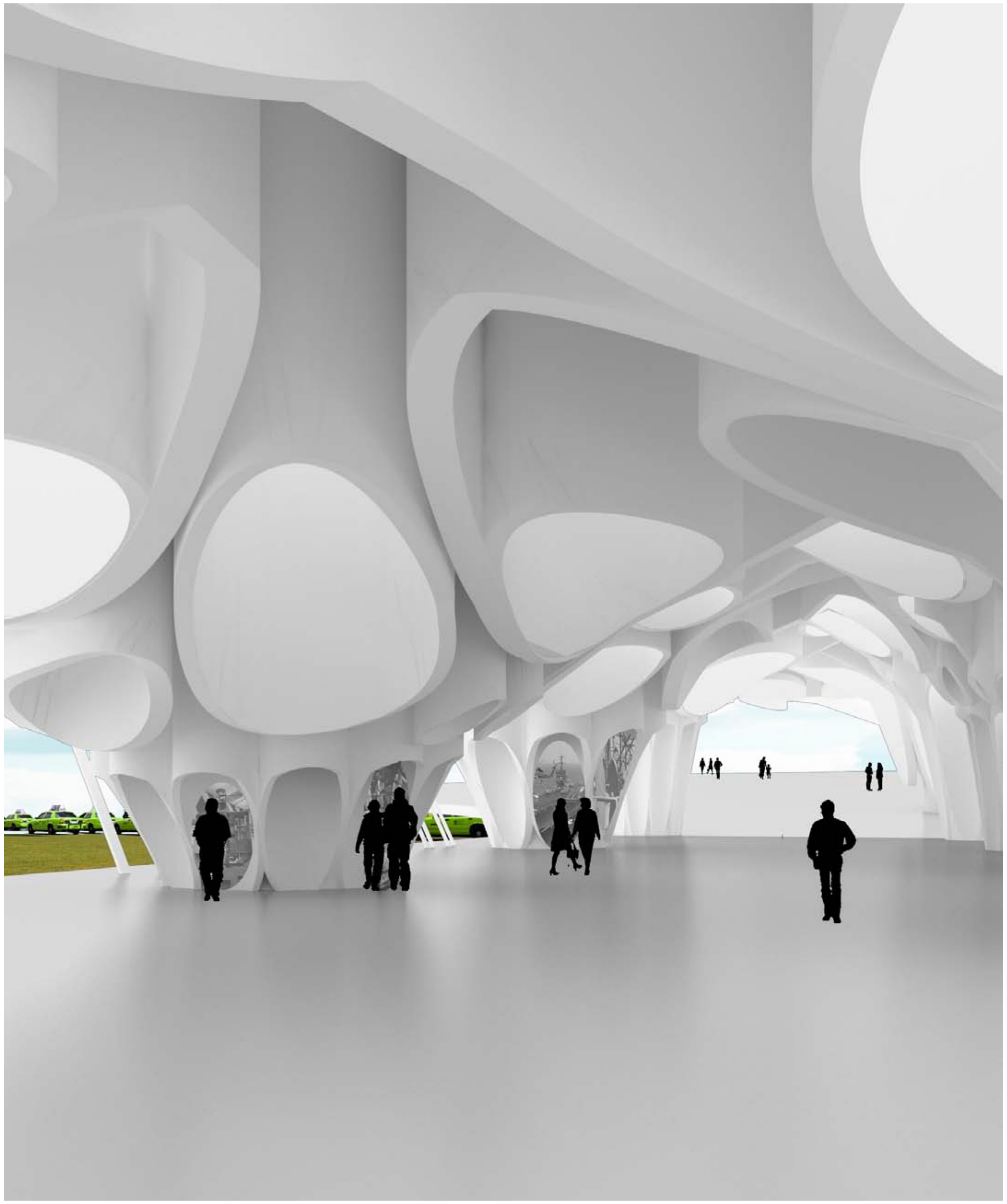
circle pack-informed voronoi variable boundary

carved bundle





hollow bundles



interior perspective looking west towards
pedestrian overpass from ground floor grand hall
image by author

view from 34th St. and 11th Ave looking west
image by author

Narrative Sequencing: The Buillding

G (Ground + Garden)

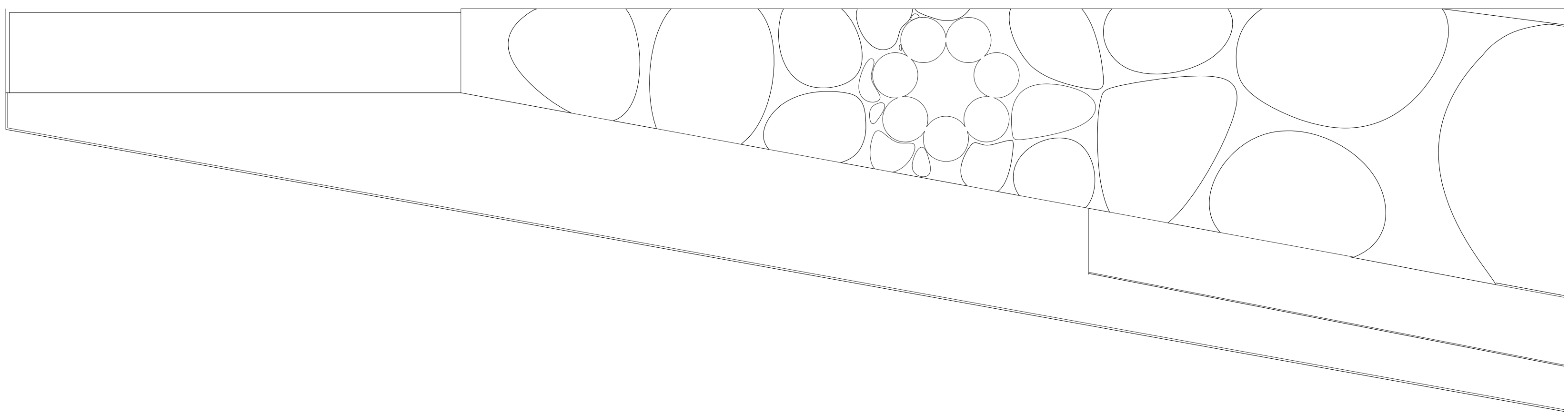
G level is the public thorough fair through the building. To the east, it begins at ground level and marks the entry to the building. As one proceeds west on G level, the site below follows the natural topography and slopes downward. Nearing the westernmost edge of the site, G level rises to meet the elevation of the Highline and passes over the highway. Upon clearing the north-west freeway, G level slopes down again, passing over public baths tucked below and slips into the Hudson River. The moment where G level meets sea level is marked by the underwater reactor research facility. This is the sole water-cooled reactor on the nuclear campus and provides heat and steam to the rest of the complex. The intersection of the G plane and the cooling pond provides clean, controlled hot water for the public to enter year-round.

Park

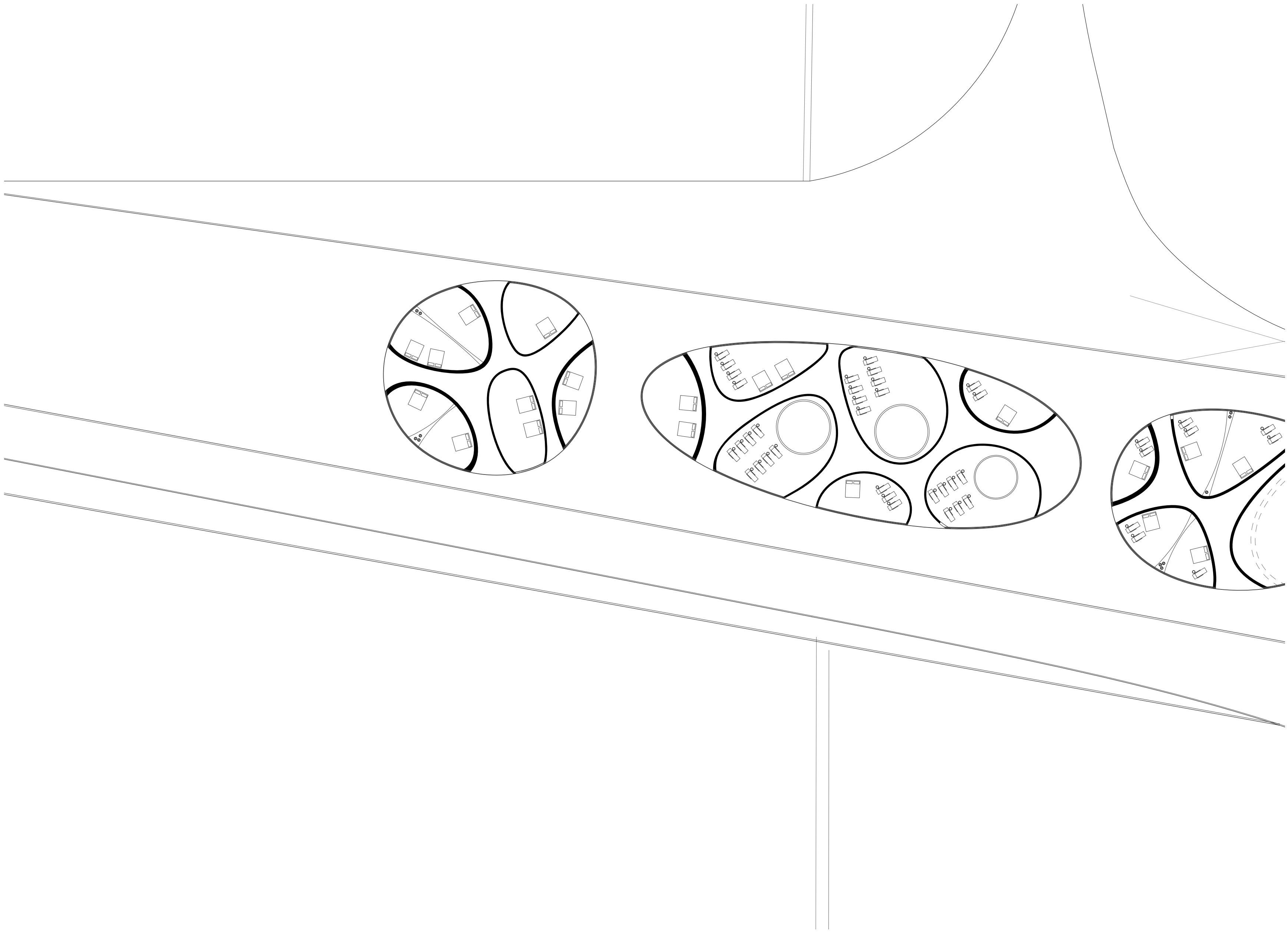
A direct circulation path connects the end of the Highline at the south-western corner of the site to the new subway stop at the north-eastern corner of the site, bisecting the city block between 33rd and 44th Streets along the hypotenuse. The Plug-in Park occupies the southern half of this division. The large public area is activated by a series of paths around planted petals. Some are the larger shapes within the park are paved, opening the possibility of a wide variety of activities to occur in the open. The horizontal petals register the change in elevation across the sloping paths of the site. Two petals towards the south of the site are programmed cooling ponds connected to the infrastructure of the underwater reactor lab to the west. The cooling ponds maintain a constant temperature year-round, steaming in the winter months and cooling in the heat of the summer. Urbanistically, the park offers relief to the massive structure to the north, allowing southern light to enter the building unobstructed. The open space also recognizes the potential development to the south (the proposed site for the Olympic Stadium) and secures the landscape surrounding the nuclear complex.

view from highline looking east towards plug in park and grand hall
image by author

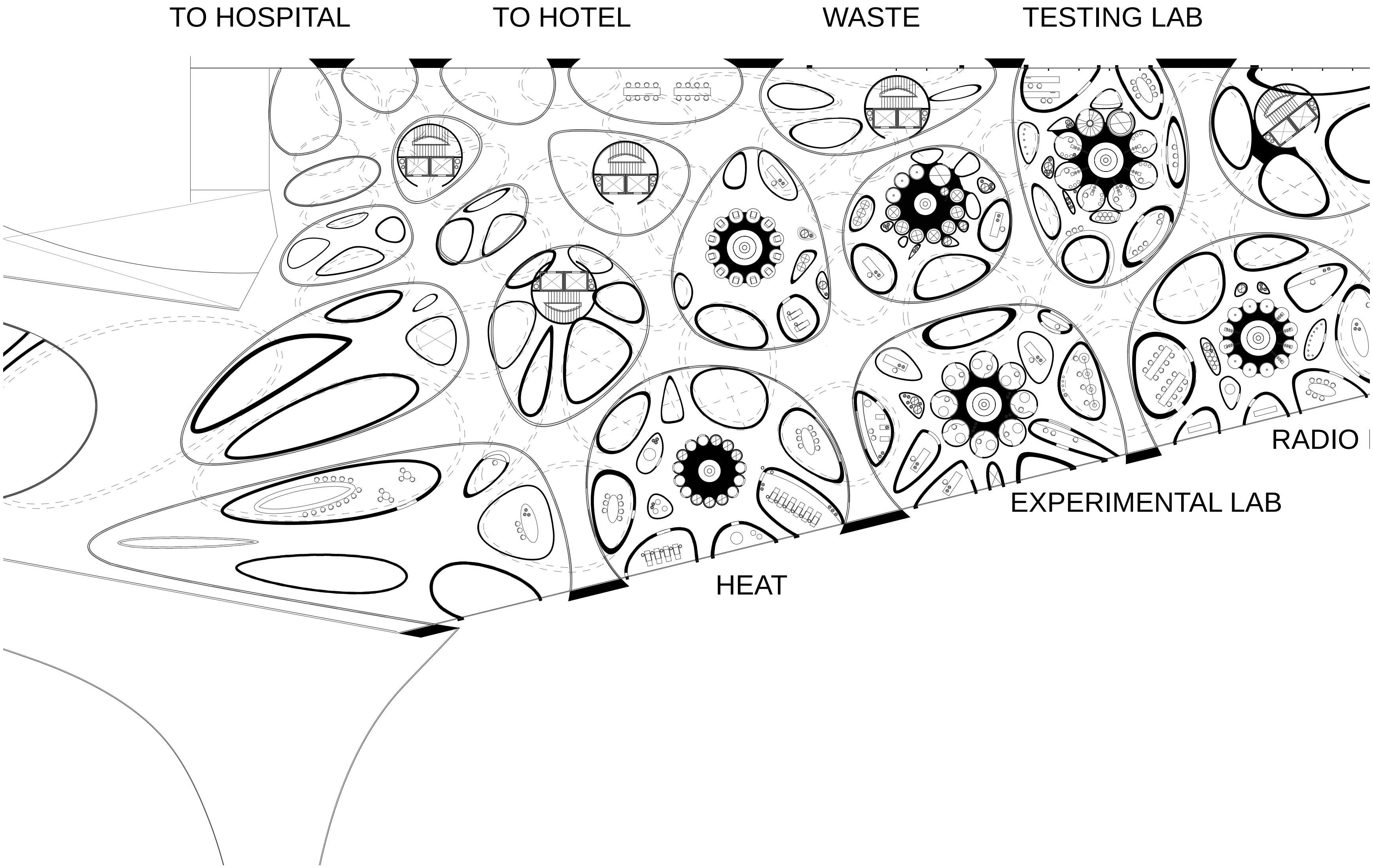
G+1 Floor Plan
image by author

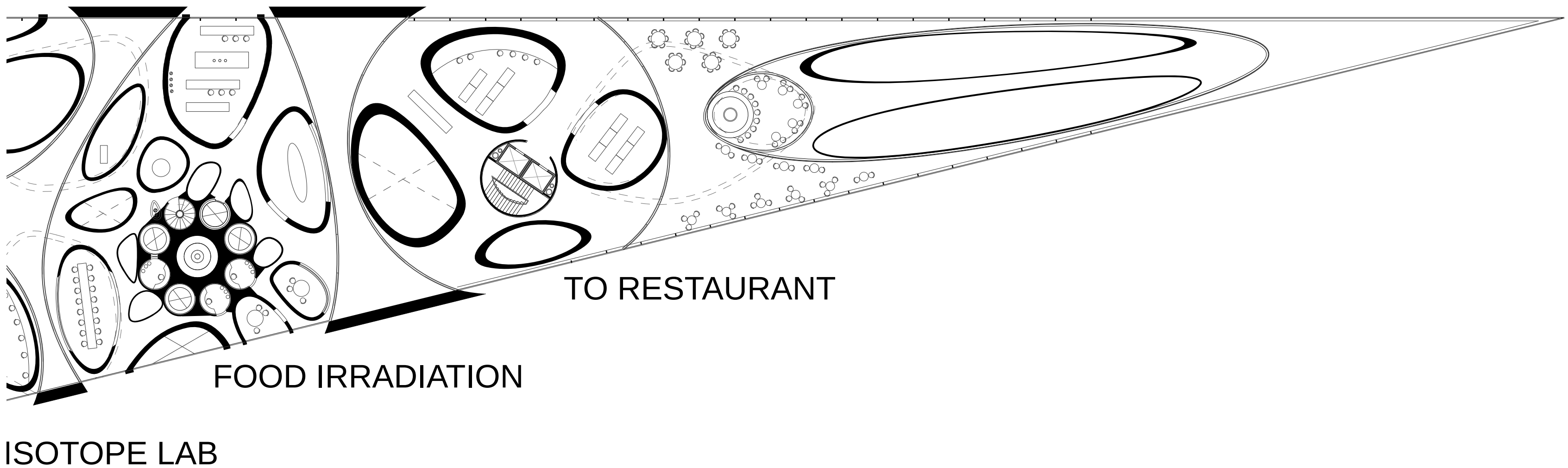


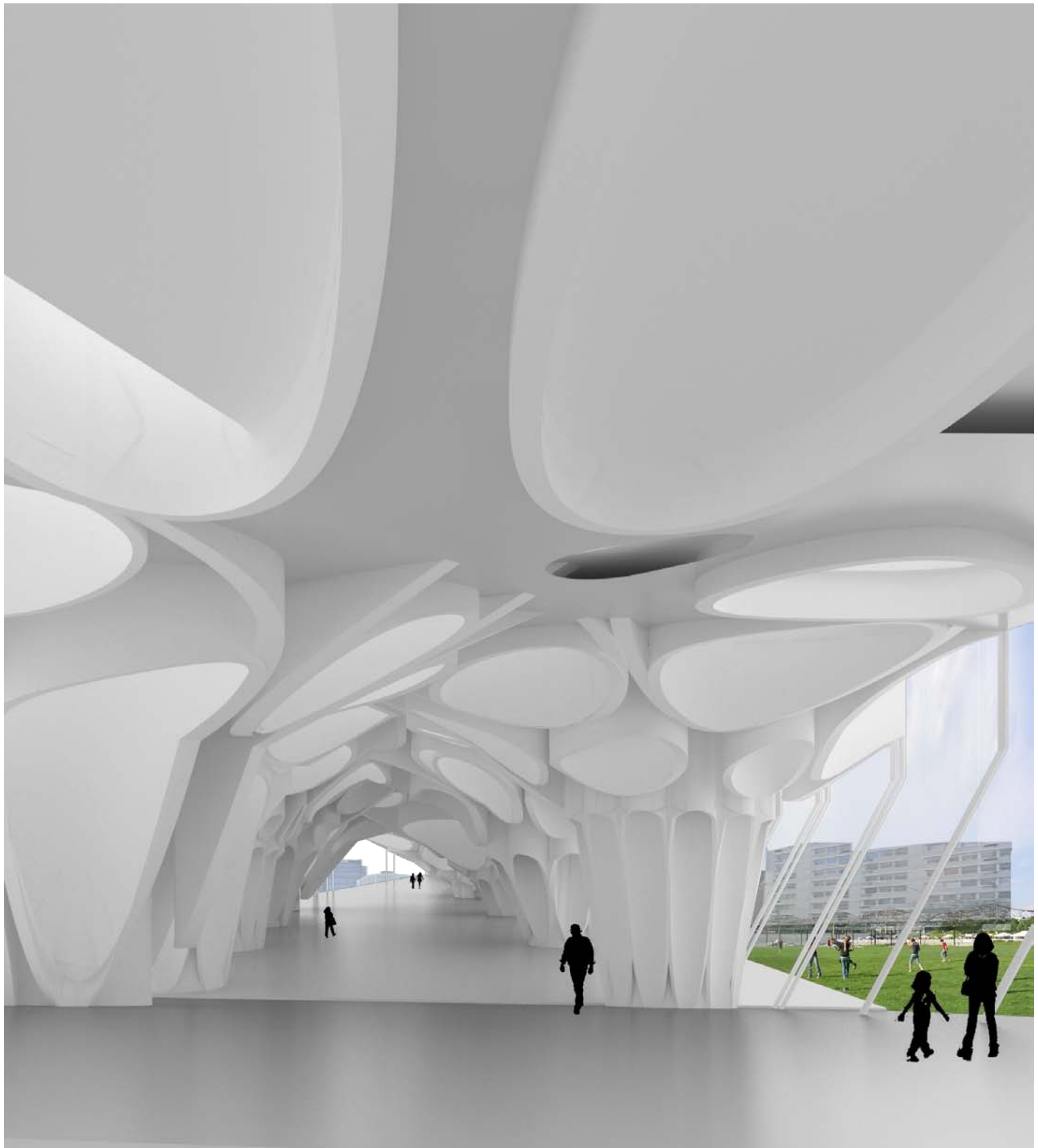
G+1
G+ 1 is the sole level in the building that intersects all cores. It is the exchange floor of nuclear knowledge, byproducts, and activity. Where security is necessary between programs, separation is treated with concentric layering, where services may pass through, but goods and people may not. The floor is the most dense, highly packed with program, mechanical equipment, and structure. G+1 is primarily a nuclear medicine facility and radio isotope lab, but also includes areas of nuclear testing, food irradiation, and circulation.



G+1 Floor Plan
image by author

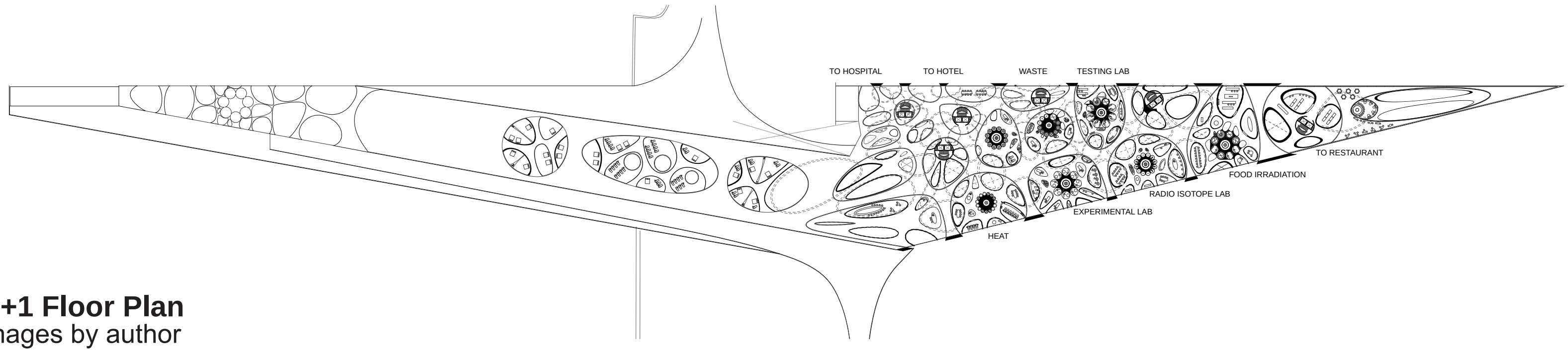



TO RESTAURANT
FOOD IRRADIATION
ISOTOPE LAB

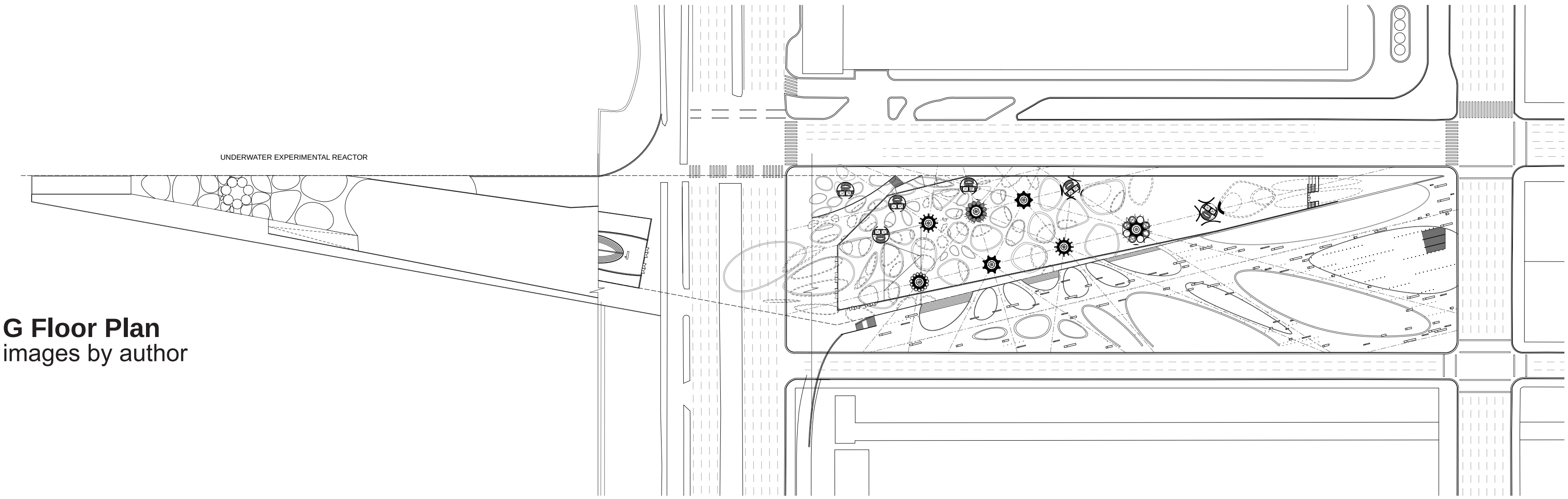

interior perspective of grand hall looking east
image by author

G+2
Nuclear medicine and imaging facility occupies almost the entire G+2 level. This nuclear medicine and imaging is the most space-intensive program on the campus. A dedicated drop off on the north-western corner of the site gives patients direct access to this floor. Just one level above the main, program-intersecting level, G+2 has direct access to most vertically adjacent programs including radionuclide research labs, radioisotope labs, the irradiated food kitchen, the wellness spa(above) and directly connects to the pathways bridging over Route 9A. Located just above the structurally bundled floor below, the cores begin to merge and encase larger spaces. Above G+1, the tubes can be removed to accommodate for larger equipment and programmatic needs. The medical and imaging facility, like the floor below, is composed of a series of circuitous paths to obfuscate views between patients and to provide a more private experience for the patients.

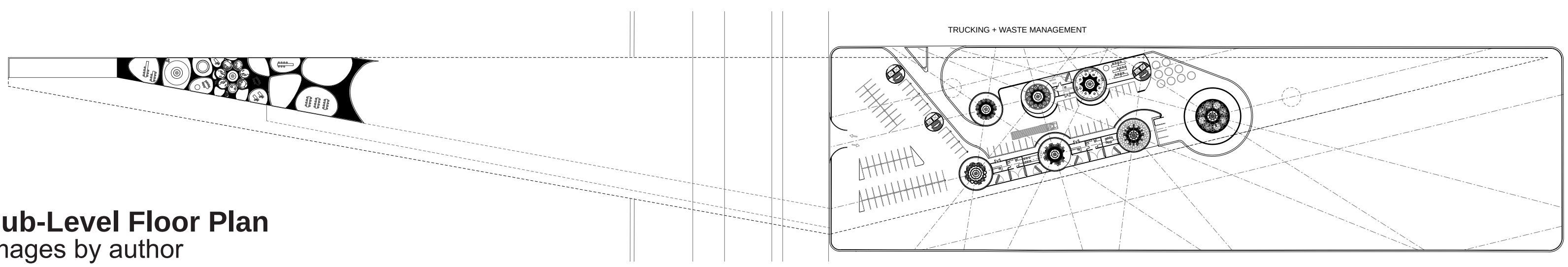
G+3
G+3 is the top floor of the facility; it houses the wellness hotel lobby, bar, and hotel rooms. Directly above the medical facility, patients have direct access to a more comfortable, more permanent stay. Upon entering the top floor through the direct-access elevator, visitors experience a breathtaking view of the city and the Hudson River. The hotel and bar are alive with activity; visitors can hope from spa to sauna seemlessly as every public path as an area of repose and relaxation. Heat rooms, sun rooms, massage rooms, and steam rooms interrupt the traditional hotel arrangement to encourage relaxation and recovery.



G+1 Floor Plan
images by author



G Floor Plan
images by author



Sub-Level Floor Plan
images by author

view from highline looking west
image by author

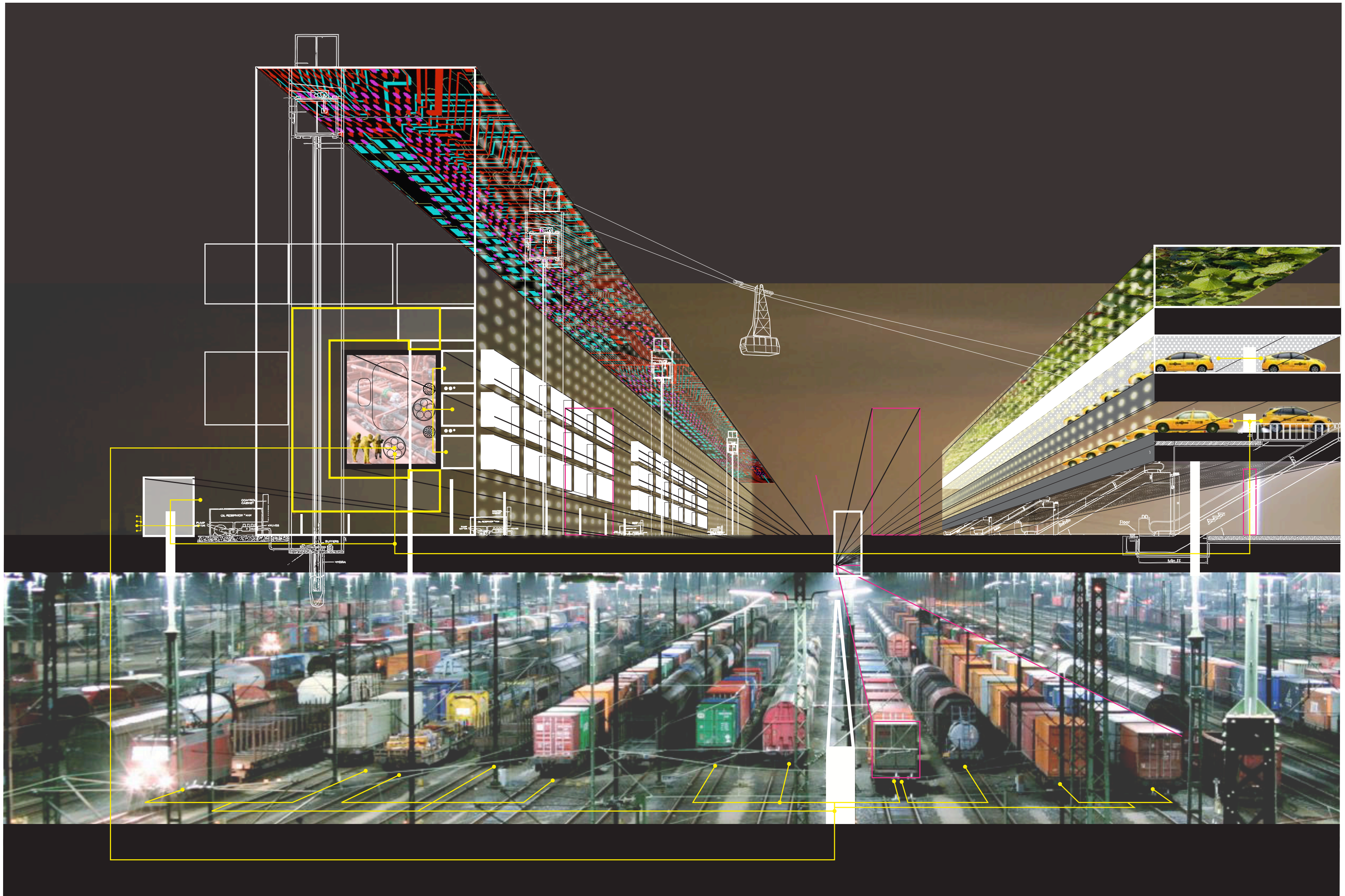
4. Continuing research

As I look back over the many directions of this project over the last year, I cannot help but wonder where the paths less traveled would have taken me. As I have noted before, this project is one of response to the many facets of advancing nuclear technology. The science and its developments have become somewhat of an obsession of mine over the last year and I will continue to pursue them. This thesis began at the scale of a nation-wide fueling and infrastructural network problem and came to a resolution at the scale of a mega-building. The direction of this project has been satisfying, but there are still so many rocks uncovered so I am taking on the nuclear field as my personal project. As I continue my research, I want to return to some of the broader issues of ways to inform the public. I want to test new ways of dissipating facts and possibilities relative to nuclear advancements. I want to continue to speak with scientists and challenge their own conceptions of what is possible for their field. I would like to return to some of my original ideas about locating this project in a vast landscape as an industrial project directly adjacent to the fuel mining operations. I plan to catalog my research and design responses, creating a visual and scholarly record of the many design implications of the ever-developing nuclear power industry.

5. Supporting Research

Disclaimer:

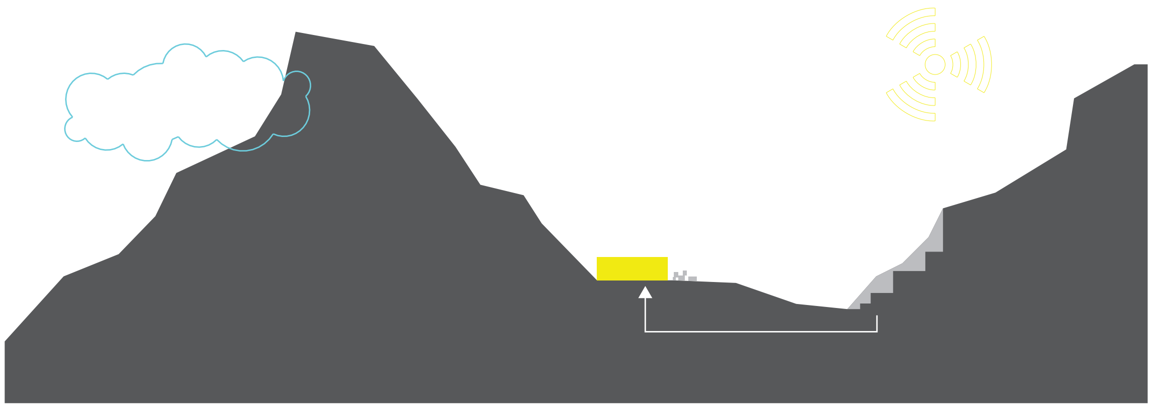
The design project in the Containment Building section of this publication is just one architectural response to a few of many directions of this thesis project. The many branches of this project continue to spread as I learn more about the field and expand on my personal project (and obsession) of investigating ways in which advanced nuclear technologies affect the public and the build environment. Thus far, I have set up arguments for rural power plants adjacent to thorium mines, submersive reactors, floating cooling tower-shaped islands, and have investigated ideas about fortification, bunkers, camouflage, and graphic media campaigns to name a few. As I continue my research, I believe I will return to some of these directions for further investigation. With that, it is important to catalog the visual, geographic, and typological references I have collected and the notes and essays which accompany them. The following are a series of essays, images, and investigations covering paths discovered but not fully taken at this point in the project.



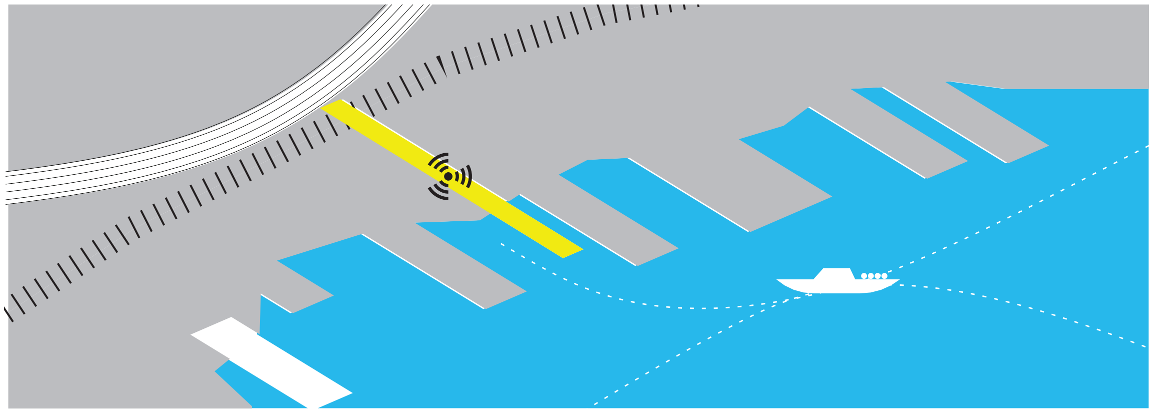
“ As the city grew, so did its electricity. Infrastructural intersections boasted endless electricity with people movers, lifts, and connections in every direction.”
image by author

“ The city that never sleeps, the city of lights, and the city of eternal seasons. The energy surplus shaped the Plug-in Park and the never-ending day.”
image by author

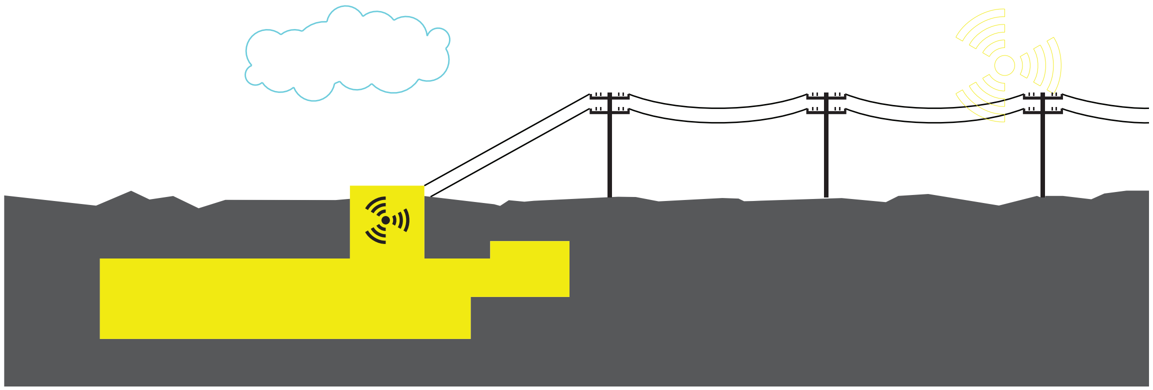
<u>Test Sites:</u>
images by author



<u>LANDSCAPE: At Fuel Source</u>
The thesis started out by assuming that my proposed project would be a completely self-sustaining system. The United States is home to the second largest reserve of thorium in the world. The ideal model, I considered, could possibly prioritize the proximity to fuel, and include mineral extraction / mining as the landscape forming part of the project. Lemhi Pass, on the Montana-Idaho border is the focus of this study. It is a historic marker on the Lewis and Clark Trail, a National Park, and the most prospected site for thorium extraction by the United States Geological Survey. While the nuclear weapons complex and waste transportation routes are both in close proximity to this site, energy consumers are not. In fact, the nearest towns to this site are 10 and 20 miles on either side. Transporting the power to large cities, some 300 miles away would be costly and inefficient. An interesting logistical comparison could arise from a cost comparative analysis of fuel transportation versus power distribution.

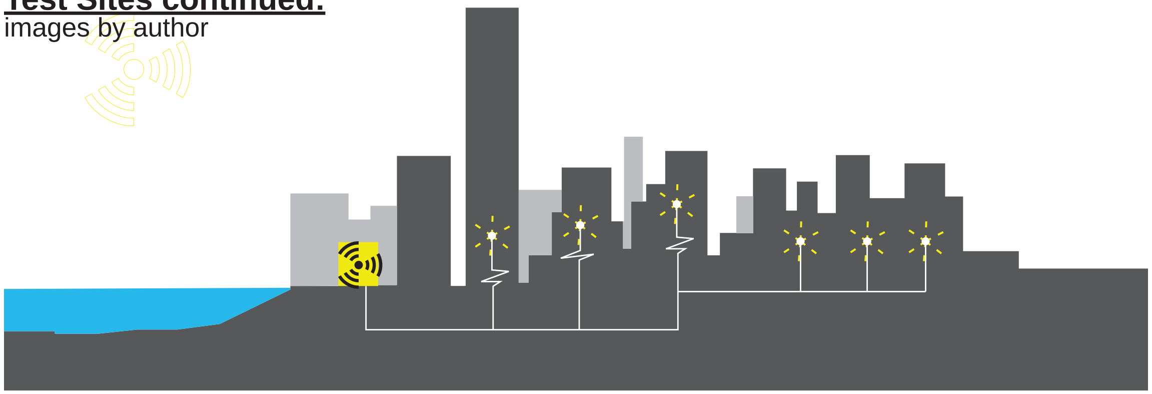


URBAN PORT: Exchange for Nuclear Materials
The United States does not currently reprocess any of our own nuclear waste. That means that it is either stored in various containment types or shipped overseas for reprocessing. The cost of this approach is incredible. In addition, most of the thorium testing is done overseas, which means that U.S. resources are also being exported to advance the research. The urban port combines the nuclear reactor, urban condition, and the crossroads of the nuclear material transportation network. By rail, highway, and sea, the confluence of these routes and the refocusing of thorium research and production in the US could occur at this node, and reverse the flow of resources.

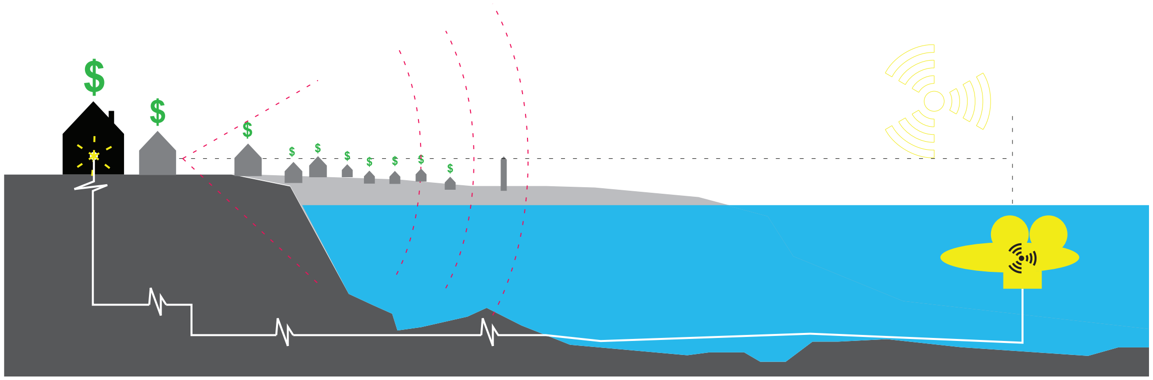


SUB-SURFACE: Underground Reactor:
Similar to the submersive reactor, the sub-surface site proposal is almost entirely hidden from the public eye. While this approach is noted for its containment of the vessel, hiding the reactor completely is not the right answer for this project. The lessons from groundwork and plant building will be noted.

Test Sites continued:
images by author



URBAN: Embedded within the City:
The Urban site, embedded within a city considers three of America's most energy consumptive and most urban coastal cities: Los Angeles, Houston, and New York City. These sites are all riddled with conflict, which I find to be quite exciting for the power station proposal. The small size of the Liquid Fluoride Thorium Reactor challenges all preconceived notions of what a power plant must be. The small footprint could possibly be embedded within an urban context and either attempt to blend in or viciously contrast the environment.

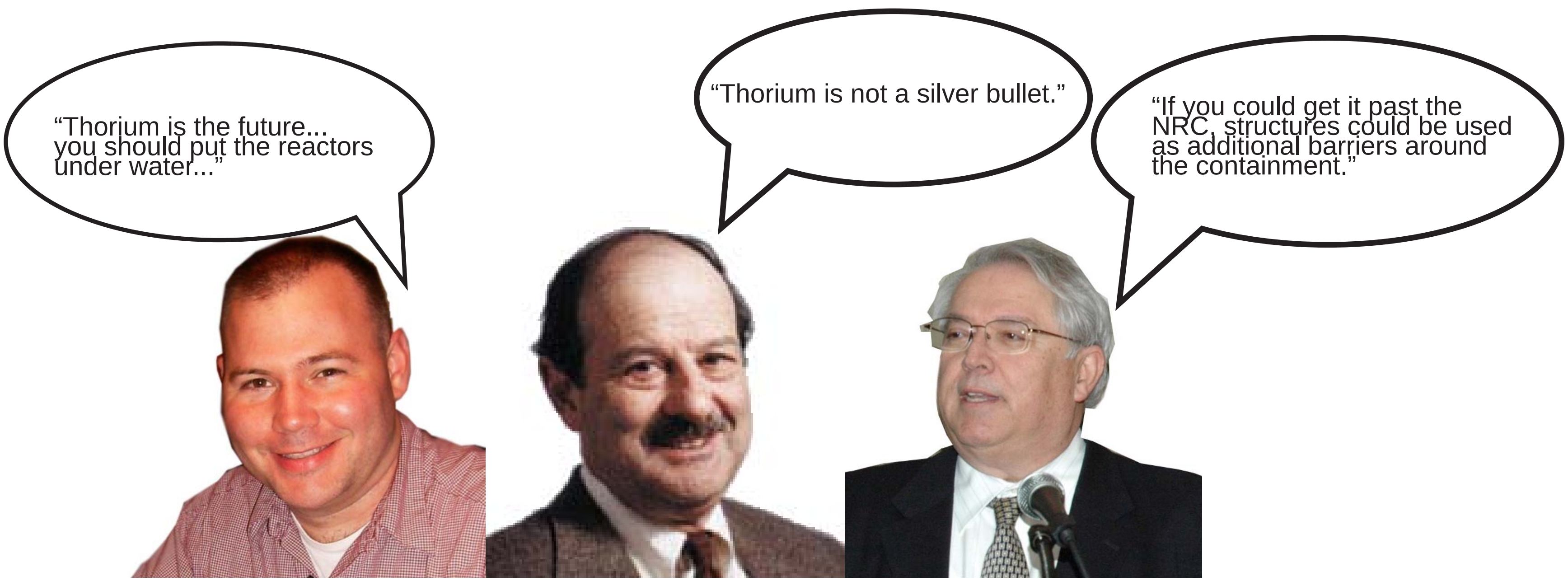


SUBMERSIVE: Underwater, Offshore Reactor:
I contacted Kirk Sorensen, an aerospace engineer at NASA and the leading expert on thorium nuclear technology. He responded to the thesis with enthusiasm and suggested that he had always considered the reactors to have a great potential as a series of mobile submersives that would dock miles off shore of large cities. There are added benefits of distance from tectonic movement, area pressure, and total removal from the public eye. Precedents for sea-bound nuclear-powered ships and submarines prove that the technology for such a model exists, however, as an architectural project I feel that the enclosure of the reactor and the conflict that the structure will embody is a powerful architectural tool, and the thesis should confront public conceptions of nuclear power head-on.

Conversations with Experts:

“I think architecture and aesthetics have a great deal to do with the level of public acceptance of any form of nuclear power. For some time, I have had a rather heretical notion of putting the LFTRs on a submersible and parking it several miles off the coast of populated areas. There are strong engineering reasons to consider this (mobility, seismic immunity, weather immunity, good heat sink, desalination potential) but the most compelling reasons may be to get the power generation close to populated areas while avoiding coastal areas that are likely populated by the richest class of people who don’t want to see a powerplant.”

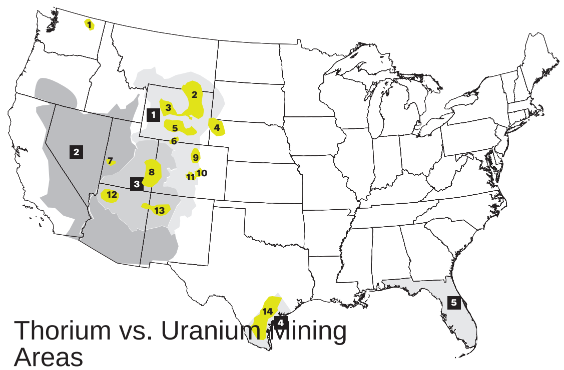
Kirk Sorensen, aerospace engineer, NASA
from personal interview



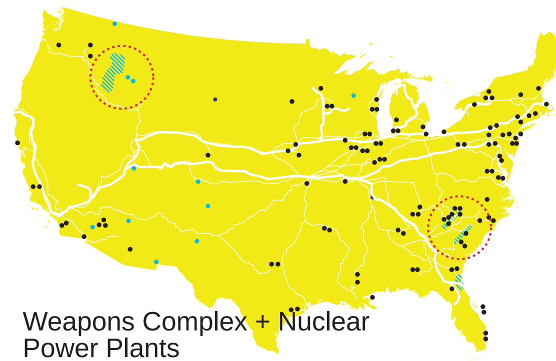
Thorium Deposits

images by author

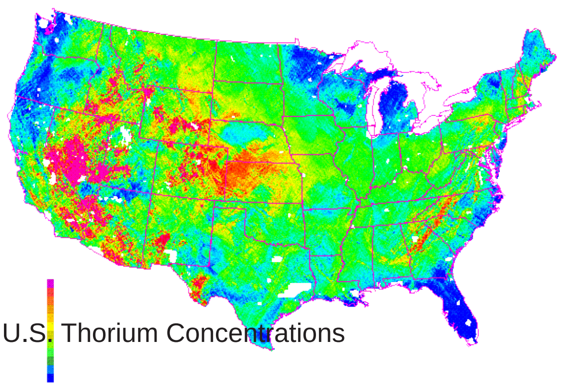
Mapping thorium locations relative to uranium infrastructure, the Nuclear Weapons complex, nuclear power plants, and major urban electricity consumers.



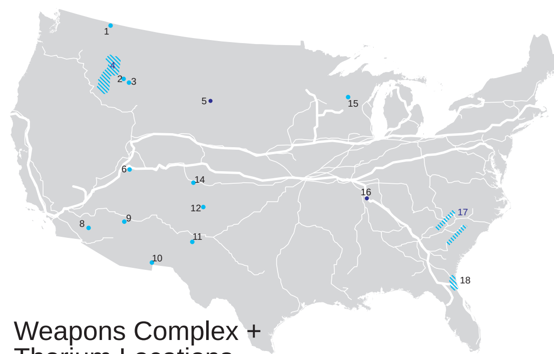
Thorium vs. Uranium Mining Areas



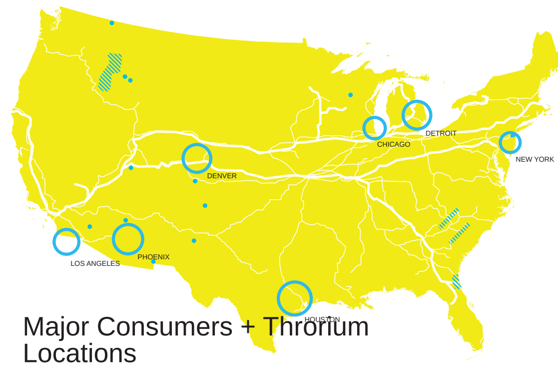
Weapons Complex + Nuclear Power Plants



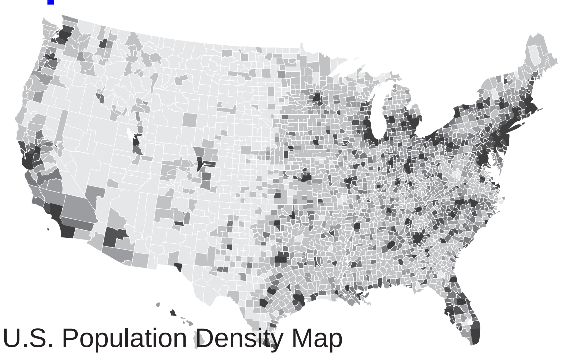
U.S. Thorium Concentrations



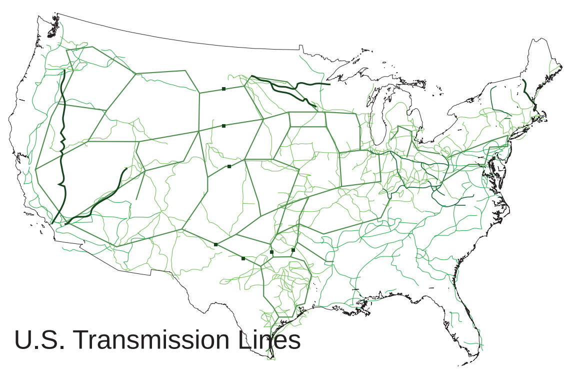
Weapons Complex + Thorium Locations



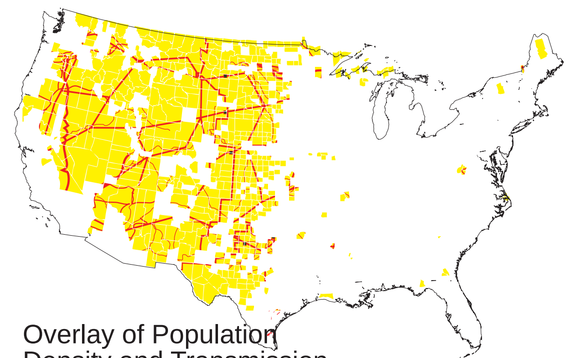
Major Consumers + Thorium Locations



U.S. Population Density Map



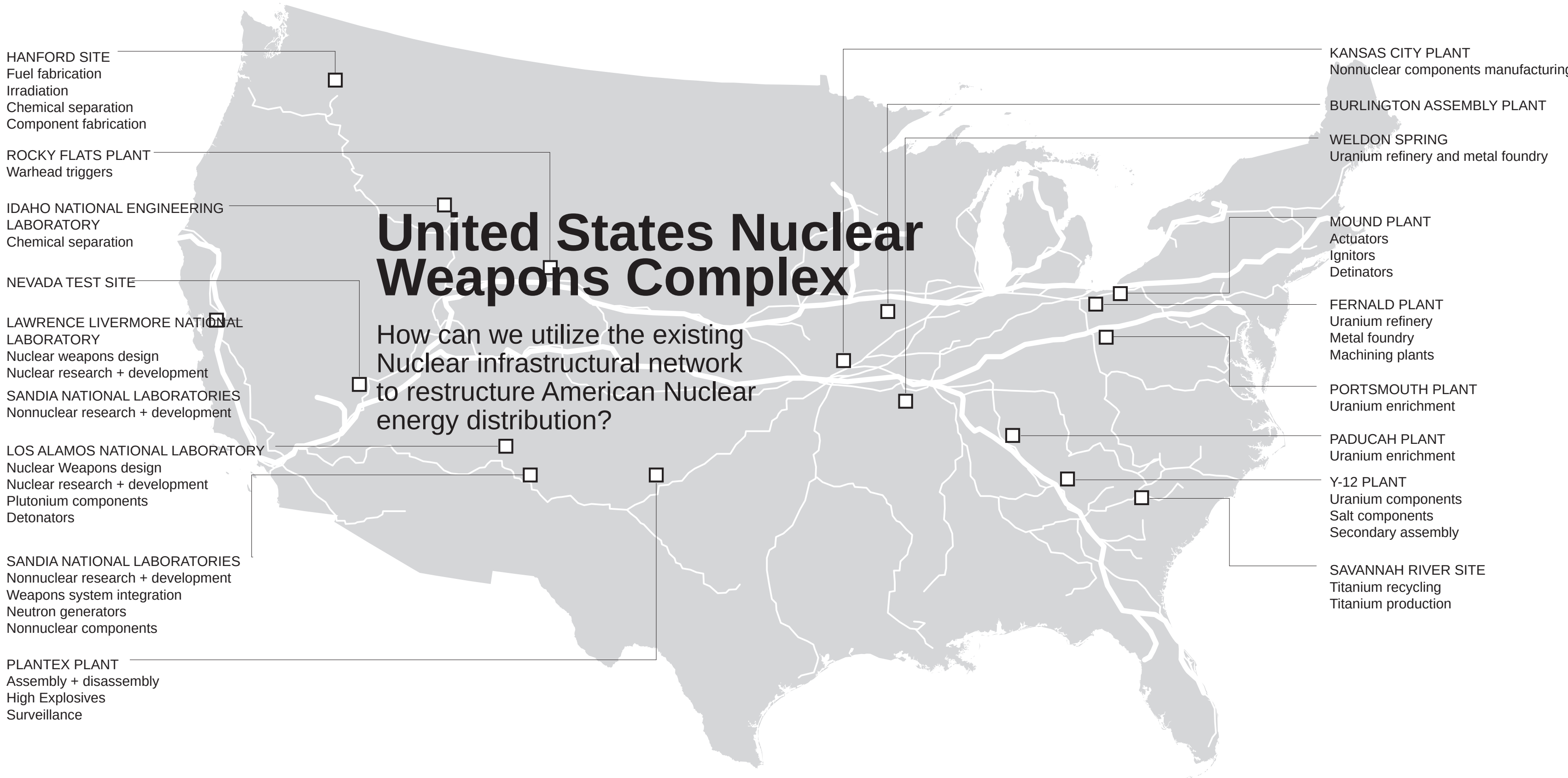
U.S. Transmission Lines



Overlay of Population Density and Transmission Lines

United States Nuclear Weapons Complex

How can we utilize the existing Nuclear infrastructural network to restructure American Nuclear energy distribution?



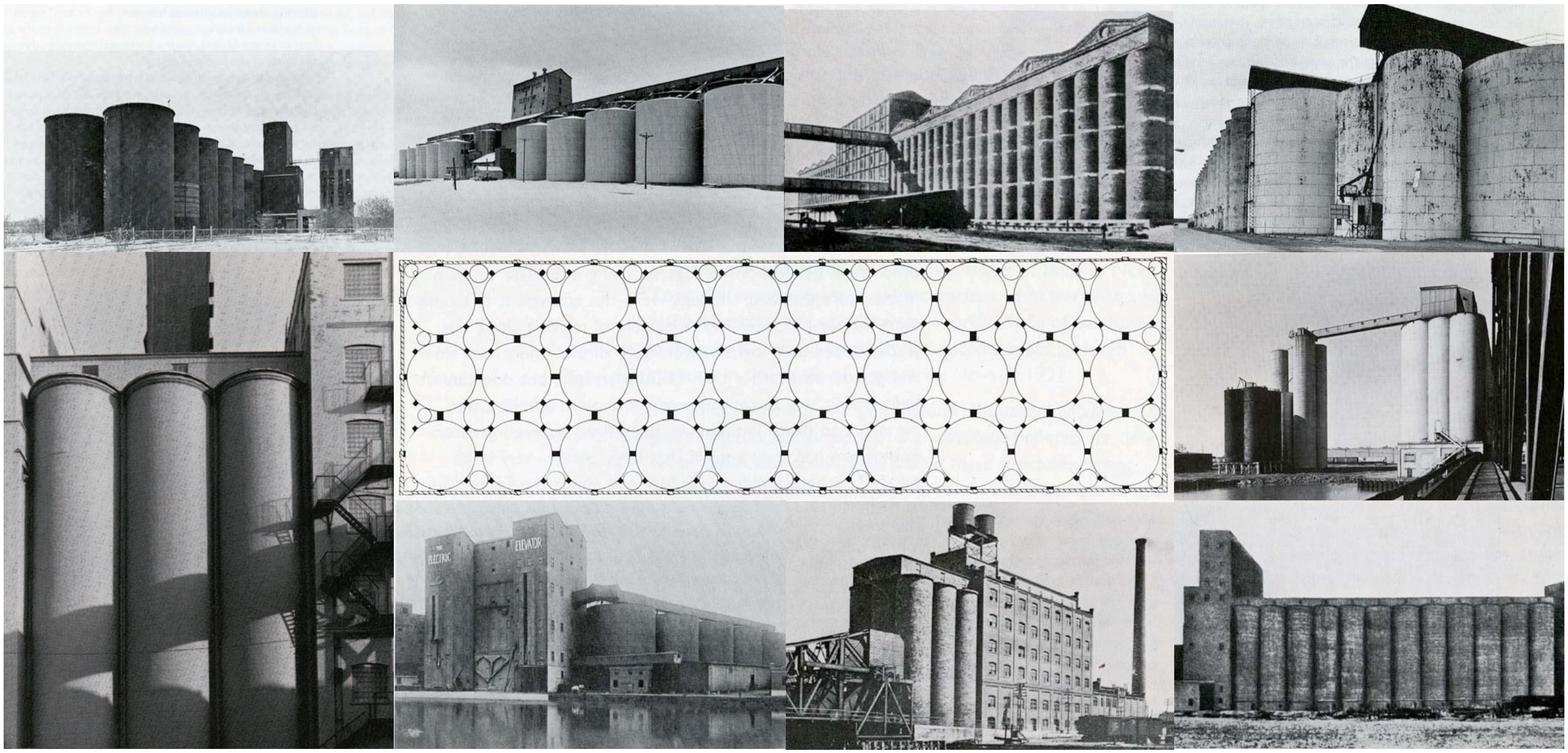


image source: Banham

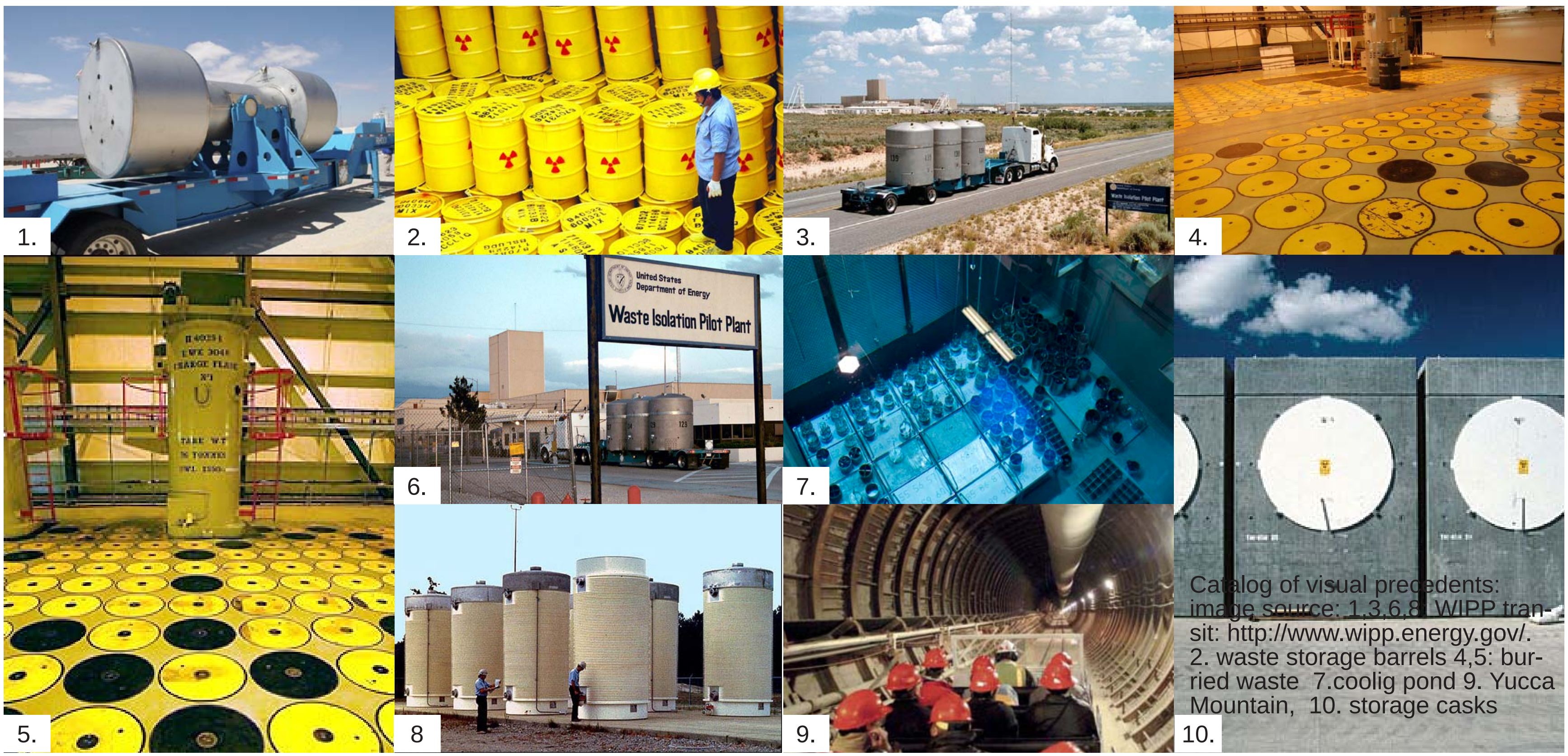
Irreducible Architecture:

Undoubtedly, the most beautiful aspect of infrastructure is that it is absolutely irreducible. Every tower, lift and curve is customized to a performative role. The cylinder of a grain silo efficiently minimizes joints in the structure while and resists horizontal forces of the weight of the grain pushing outwards. The height and pressure of the grain above aids the fermentation below. The hyperbolic curve of cooling towers simultaneously offers structural efficiency, buoyancy driven air flow, and reduction of condensation into the atmosphere. Each formal move reveals not only the task assigned but also the physics of how each move is executed. It is a completely honest approach to design, so functional in nature that their design is usually left to engineers. One main reason is that, for the most part these infrastructures do not need to address human occupation; they are simply large containers and machines operating at the scale of architecture.

But functional demands for human conditions have historically had a large place in building. Some of the earliest examples include protected structures of political power, as exemplified by any examination of early military architecture, fortifications, or castles. The development of the pentagonal shaped form, for instance, grew out of a need for surveillance and weapon deployment in the round. Lessons from attacks soon initiated a need for a maximum circumference at a minimal footprint. Highly acute walls and concentric plans made difficult the penetration by human force or weapon impact. As the prospect of attack from above became more of a threat, architecture necessarily transformed in the third dimension. The most interesting of these typologies is found when the rationale behind the most efficient, productive infrastructures has a direct influence on human-occupied protective architecture. For example, characteristics of both nuclear power plants and protective architectures are seen in the construction of Cold War military bunkers. Detailed with reason and efficiency, evidence of traditional layering of concentric plans in the round, as well as a massive layering of protective earth above, there is not a flippant aspect of these facilities, yet they are stunning. The architectural finesse occurs where traces of utilitarian human needs meet extreme pragmatism. Panoramic slits are cut into the massively thick walls, wedding maximum surveillance with protection. The same characteristics become mirrored as the threat of nuclear attack backfires on nuclear energy protection and power plants begin to take the shape of bunkers. The following comparative visual catalog examines a number of Cold War bunkers and places them adjacent to Nuclear Power plants. Formal similarities can be found in protecting themselves from the demise of proliferation.

Waste: On-site storage and handling

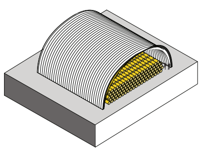
Nuclear waste disposal and transport is another key factor in the siting and design of a nuclear plant. While Thorium reactors produce much less nuclear waste and zero carbon, it is not a zero waste system. However, research is currently being conducted (and will be conducted on site) on how to deal with this hazardous material. Currently, barrels of waste from molten salt reactors are being stored above ground, protected from the elements, with prospect that the waste will be utilized as fuel. In addition to a plant's own waste, researchers also claim that plutonium-contaminated waste from light water reactor plants can be used to initially trigger reactions in LFTR. This would involve a close investigation of nuclear waste storage facilities and the infrastructural network that supports its transit. Precedents for waste storage range in scale from mountain ridges to shed structures. Nevada's Yucca Mountain is a storage facility-on-hold that has been in development since the early 1980's. Burrowed underneath a volcanic ridge, Yucca Mountain is the potential home to thousands of barrels of nuclear waste. Another facility is the WIPP (Waste Isolation Pilot Plant) which burrows into a bedded salt formation in the desert of southeast New Mexico which permanently disposes of defense-related, transuranic "true waste" nearly a half mile underneath the earth's surface.(WIPP website) At a much smaller scale, waste can also be stored in above ground dry casks: cylindrical storage con-



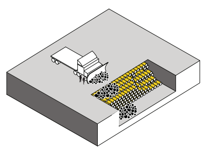
1. 2. 3. 4. 5. 6. 7. 8 9. 10.

Catalog of visual precedents: image source: 1,3,6,8: WIPP transit: http://www.wipp.energy.gov/. 2. waste storage barrels 4,5: burried waste 7.coolig pond 9. Yucca Mountain, 10. storage casks tainers that let radioactive waste cool while keeping the material accessible for possible future reuse.

Waste Management Facilities:
Nuclear waste is currently handled and stored in a number of ways, depending on the radioactivity of the material stored. The largest facilities consist of large underground complex thousands of feet underground, while temporary, less radioactive storage methods simply store waste above ground in barrels until the radioactive decay has reached a minimum level.

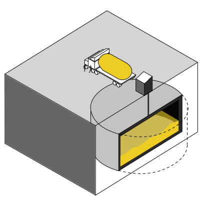


Low Level Radioactive Waste, temporary above ground storage barrels



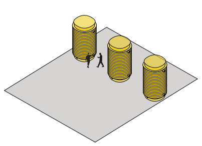
Low Level Radioactive Waste, burried barrel storage

10x



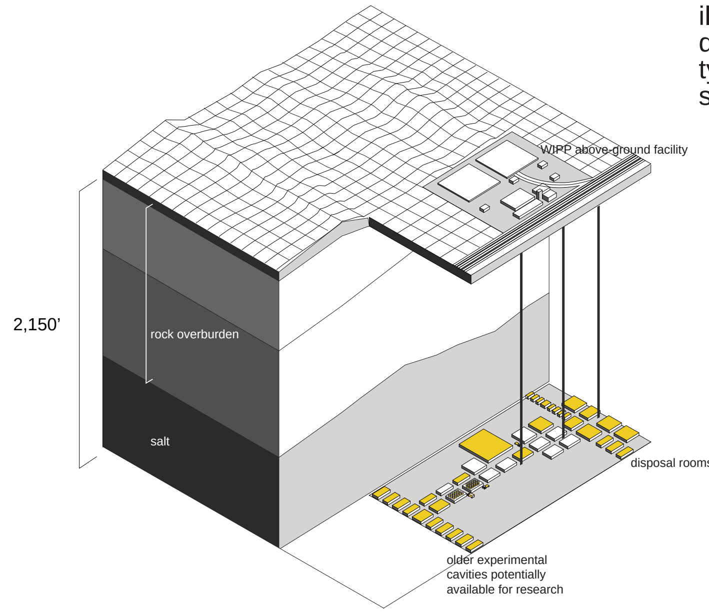
75' diameter burried steel and concrete drum

20x

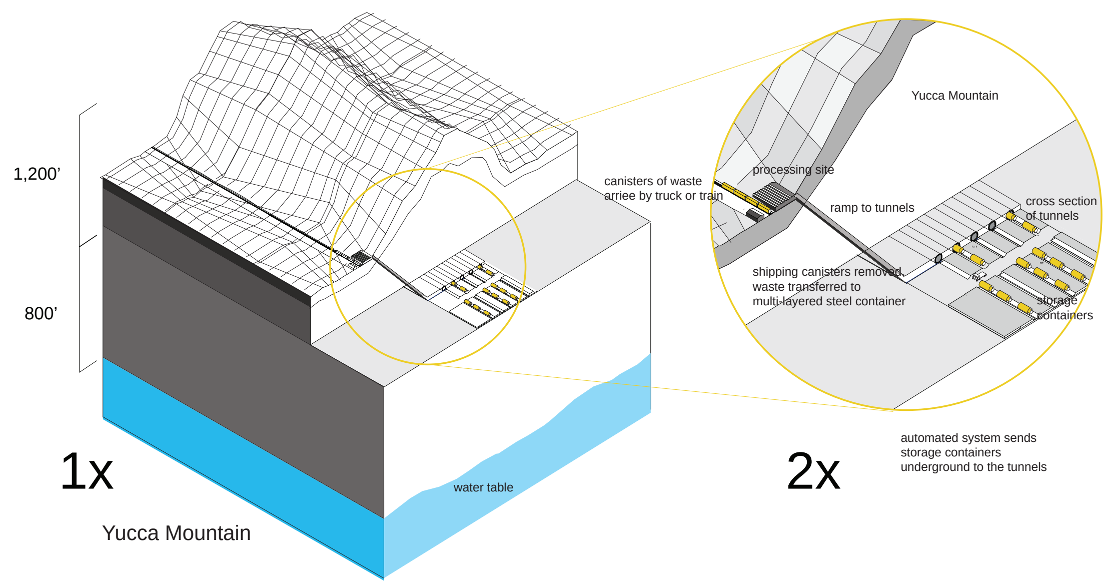


High level waste above ground storage casks, potential waste re-use

illustrations by author
drawings displaying the different types and scales of nuclear waste storage.



WIPP: Waste Isolation Pilot Plant

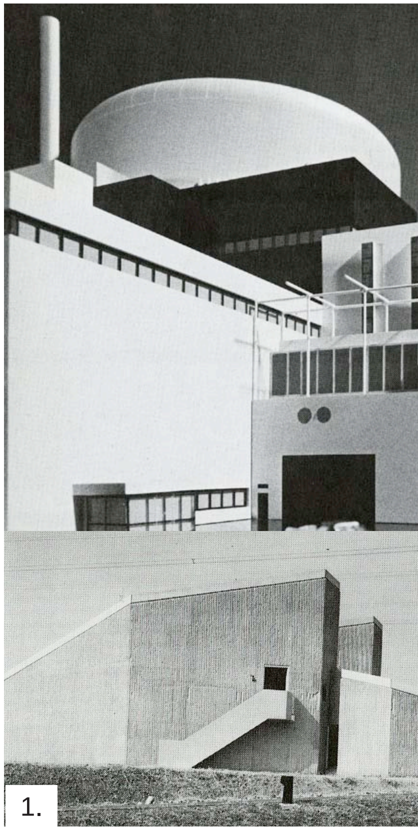


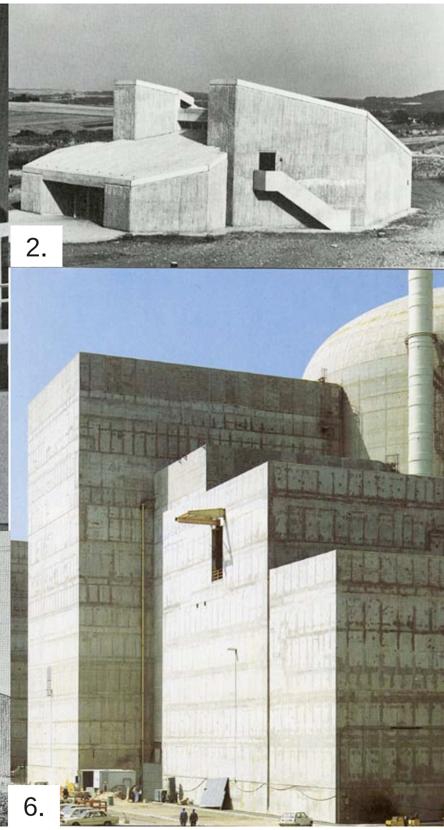
1x

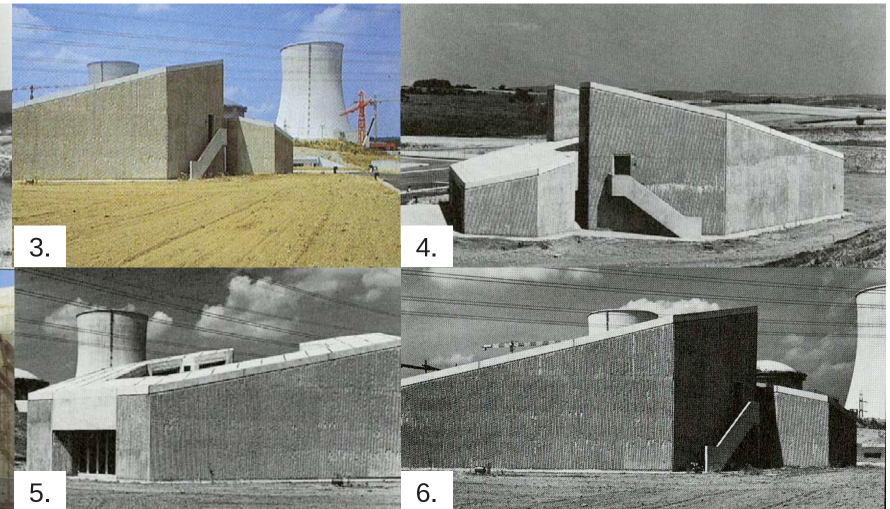
Yucca Mountain

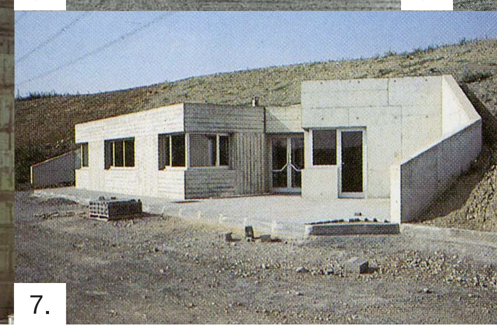
2x

Containment:



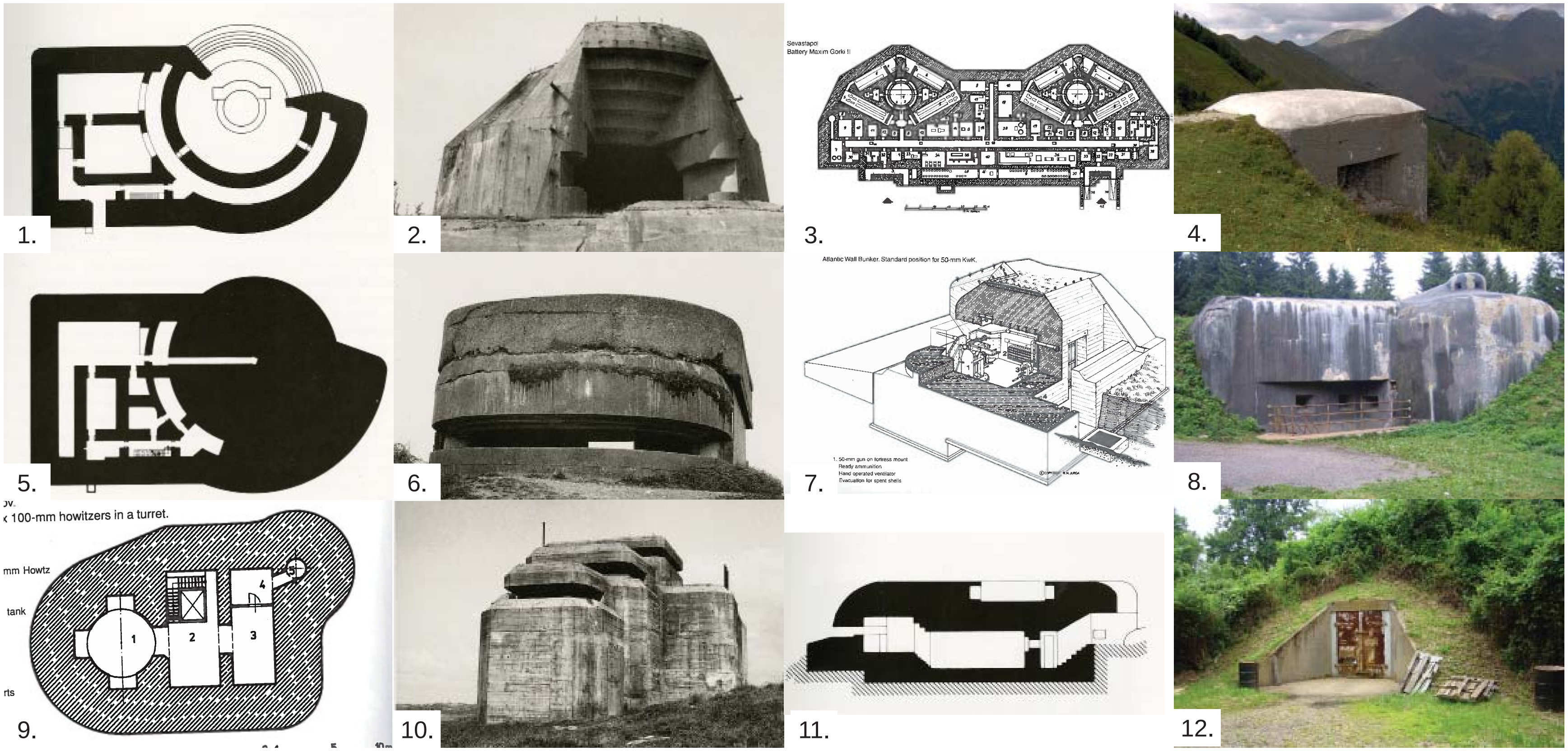






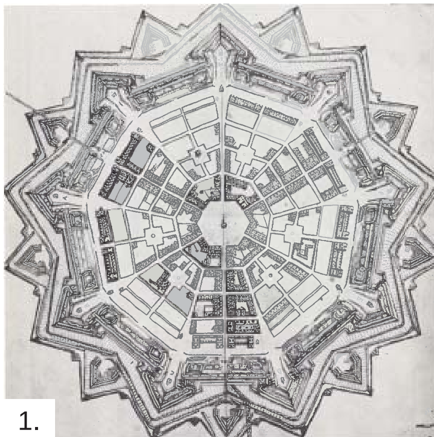
Catalog of visual precedents:
Nuclear Power Plants
image source: Parent

Bunkering:



Catalog of visual precedents:
Cold war Bunkers
image source: Virilio

Fortification:



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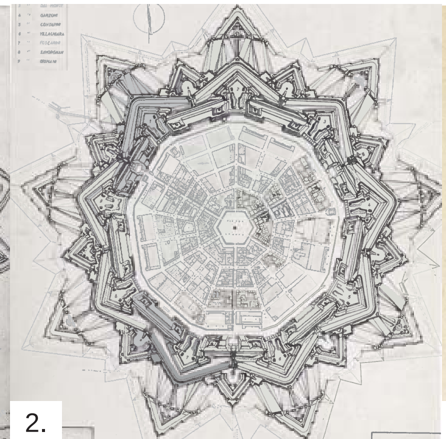

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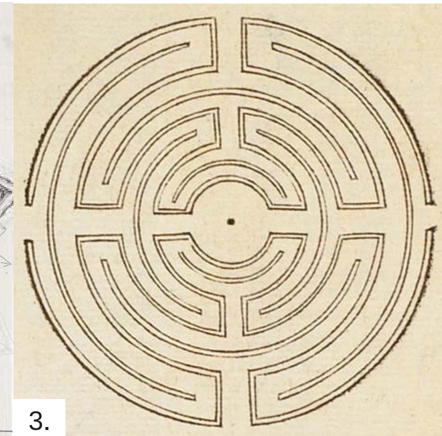

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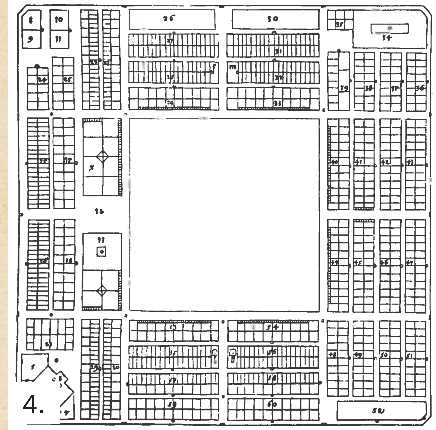

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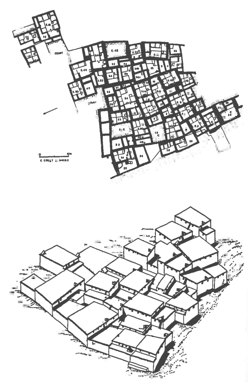

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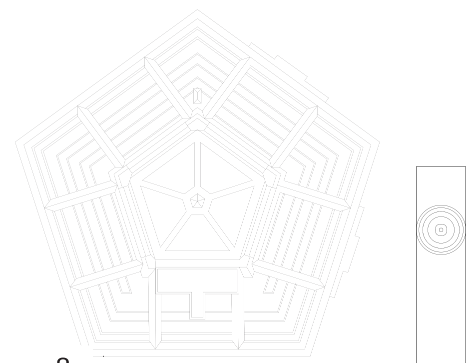
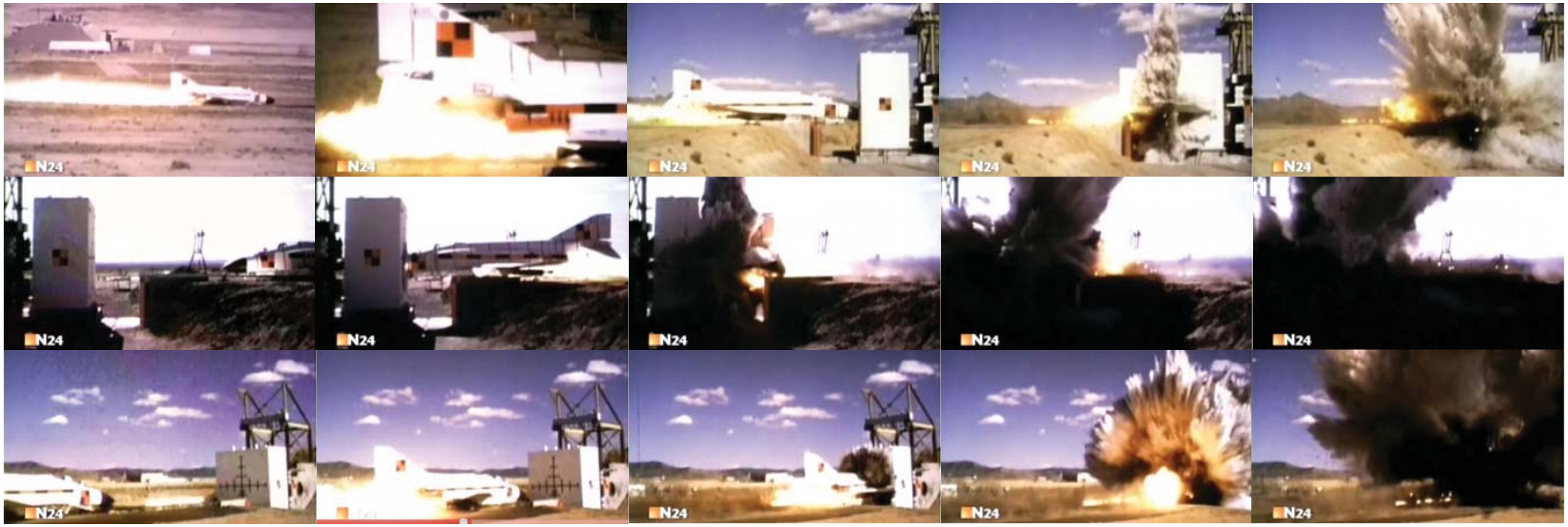


8.

Catalog of visual precedents: image source 1,2,4,5,6,7: Newberry. 3: http://www.labyrinthmeditation.com/images/ChartresLabyrinthBrushbox.JPG 8: by author

<u>Material and Structural Security:</u>



Screen captures from structiral test video. Images display jet running into concrete wall of containment building, destroying the jet and leaving the wall unharmed:
video source:
http://www.myvidster.com/vid-
eo/802703/What_happens_if_a_
jet_hits_a_nuclear_reactor_conta

Nuclear Tourism:

Post cards from the Nevada Test in Las Vegas, NV.
scanned documents collected by the author

Post card from French nuclear power plant visitor centers and town shops.
image source: Radiance of France

NOTES ON TOURISM:
Touring the Nevada Test Site with Ernie Williams

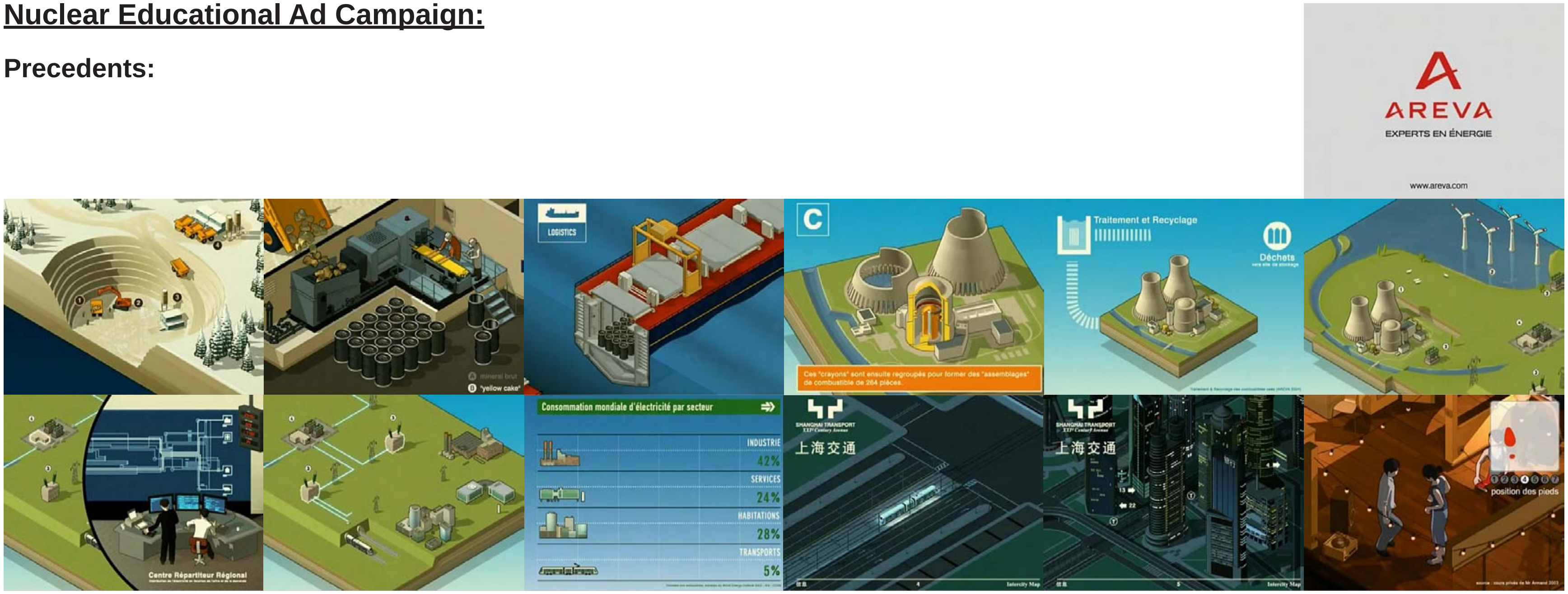
At 7:30 am, August 24, 2010 I waited outside the Atomic Testing Museum along with 33 other anxious, pant and boot wearing visitors in Las Vegas, Nevada. Reservations for the once-a-month public tour fill up months in advance so we, myself along with all the other nuclear tourists, were eagerly poignant. The museum was a clean, modern buildings outfitted with glass. large mullions, and stainless steel panels. It is home to some of the University of Nevada, L.V. research offices, a government testing office, a public reading room, and a gift shop. Our tour guide, Ernie Williams, a short, baseball cap-wearing veteran made the first rounds of introductions. He was one of the first members of the test site team and was present and active at the Site for over 55 years of testing. We loaded the bus and departed at 8am sharp after being cleared and searched to make sure there were no cameras, cellphones, or any other type of recording equipment. We embarked on an hour long drive to the Nevada Test Site. Ernie played Test Site Documentaries on the way, highlighted by interviews starring none other than Erie Williams himself. The landscape of casinos and high rise hotels quickly dissolved into the sparse Nevada desert speckled with mobile trailers, a few gas stations, and a prison. As we approached the site, small developments (or remnants thereof) of testing towns began to appear. We are told that at one time, nearly 10,000 employees commuted to the test site from the surrounding Nevada area.

The test site is heavily guarded by a series of manned posts, signs warning the forbidding curious trespassers, and a barbed wire holding pin with a port-o-let for those who challenge the rules. A guard boards the bus, checks our badges and grants us to enter. The site is a vast 1,360 sq. miles of desert and mountainous terrain protected by a even greater ring of mountain ridges that protects it from the 100yr flood plane. The tour was nothing short of stunning. Ernie's first hand accounts of witnessing the testing enlivened the remains of each site. We were bussed to various detonation locations and inspected the houses, structures, mounds, and cages that were arranged at controlled distances from ground zero. Varying depths and diameters of craters indicated different placements and intensities of detonations. Most interesting was learning about the number of disciplines that participated in and benefited from the testing, including: architects, engineers, doctors, medicinal experts, fabric engineers, automakers, and countless more. It is this branch of the nuclear testing industry that is most relevant to this thesis project and its affect on people. Medical advancements, structural and material soundness, and capturing energy all advanced due to these tests. The tour bussed us through waste disposal sites, detonation sites, and even allowed us to walk around the grounds of a few tests and a crater. The tour proved, as I have uncovered in my research, exactly how careful and safe the industry is. Geigger counters and dosimeters were attached to the tour crew and pebble sample tests were taken and tested from the bus, all to ensure that no radioactive particles were picked up. The same extreme precautions were taken at the test reactor on MIT's campus. While neither of the tests showed any exposure, the system is in place to ensure the public, security, and environment that nothing harmful is escaping the site.

While touring the site, what was of particular interest to me was observing the other visitors. I have my own, clear reasons for being interested in America's connection to the nuclear cycle and the historic steps that America has taken to advance nuclear science, but what is it that maintains a waiting list needing reservations four to six months in advance? Many of the visitors were veterans of varying sectors of the military, a few were teachers, and the rest were a medley of different professions, all interested in America's nuclear past... and future. While in the tour, Ernie (not only a veteran, but also one of the founders of the Atomic Testing Museum) had no reserves about expressing his pro-nuclear opinions, not limited to testing, but including nuclear power. He was well versed on the politics and science of storing waste and the conflict surrounding both and stressed to inform eager ears about his own encounters, and absence of medical problems. The entire bus, it seemed was a pro-nuclear crowd from all across America, agreeing that informing the public and education were key to changing the misconceptions of the American public about nuclear science and power. Like the visitors to the French nuclear facilities when nuclear power was first being introduced in France, many were proud, interested locals participating in the nuclear past and supporting its future.

Nuclear Educational Ad Campaign:

Precedents:

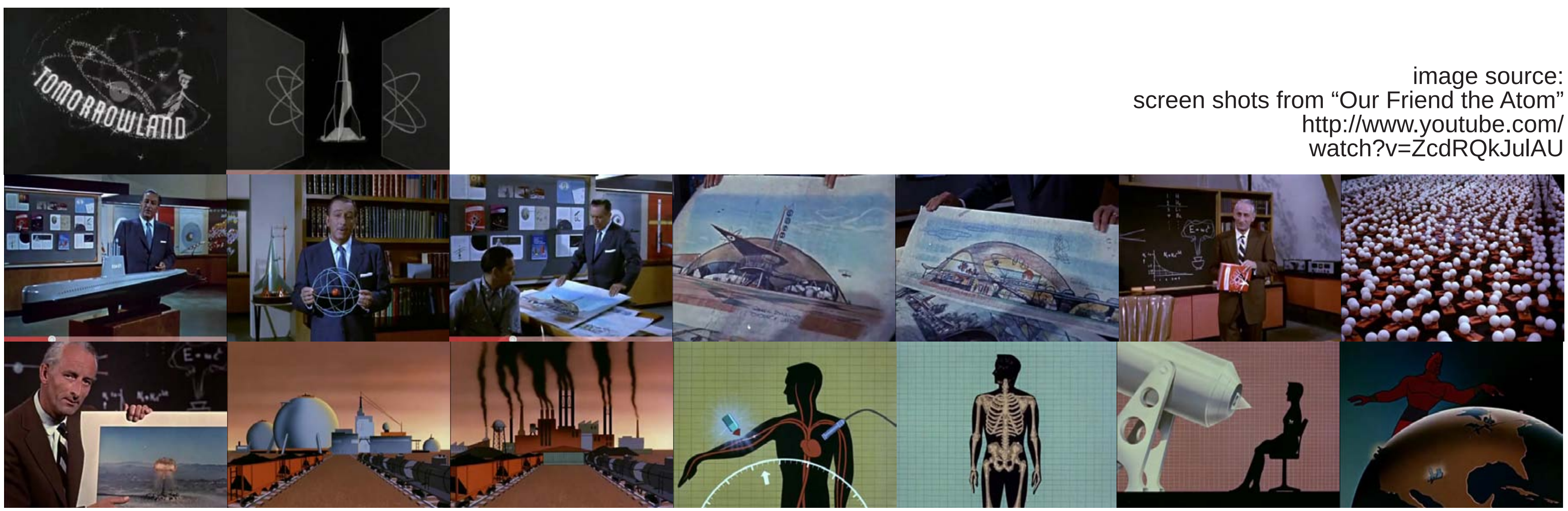


AREVA, a multi-national industrial conglomerate, launched an award winning animation sequence promoting nuclear power, illustrating nuclear power processes and its presence in daily life. The short was set to “Funkytown” by Lipps. Inc.

image source:
screen shots from AREVA commercial:
http://www.youtube.com/watch?v=k3_hLTKiIZE

Walt Disney launched a campaign in 1956 entitled, “Our Friend the Atom,” to educate American children on the benefits of nuclear power. The campaign exists in both book and video format.

image source:
screen shots from “Our Friend the Atom”
http://www.youtube.com/watch?v=ZcdRQkJulAU



<u>Nuclear Educational Ad Campaign:</u>
Graphic Tests:
all images by author

The most significant contrbuting factors to anti-nuclear sentiment are ignorance and misinformation. The first stage of the nuclear campaign is to educate the public.

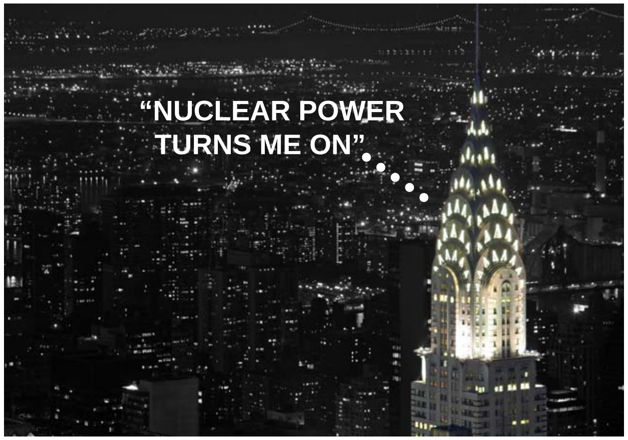
“Nuclear Power is the only zero-carbon technology able to provide consistant, base load power to the world.”

Nuclear New York Ad Campaign:

Graphic Tests:

Turn on New York

The next step in addressing the public is introducing levity. The public is largely fearful



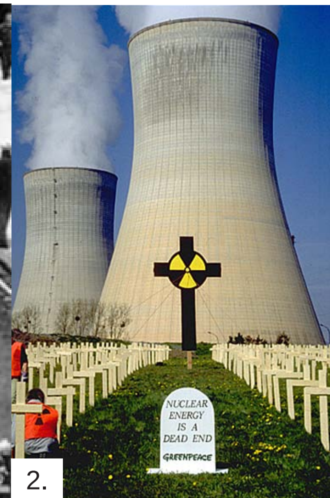
NOTES on Experimental Testing Labs:

The Experimental Reactor

I entered the building through a small, brown, scarcely marked door equipped with what looked like a residential door bell. Greeted by Andrew, an undergraduate suited in a fitted white dress shirt, striped tie, and dark dress pants, complete with pocket protector, radiation moderator, and identification lanyard. The tour starts with a quick facility briefing, handing over identification, signing in contact information, discarding all bags and coats, and signing out a wearable radiation meter. Passing a few Geiger counters and rows of hanging hazmat suits and protection equipment, we are met by a large, seafoam colored door, one that is reminiscent of a submarine hatch. Andrew punches a code, swipes his identification and looks into a retinal scanner that allows him to open the door. We entered an antechamber and at the push of a button, the entry door slowly closes behind us and an air-tight lock pressurizes the room. For a quick moment we are engulfed in a sea of 1950's paint in a symmetrical, sealed room. No sooner does the hatch at the other end and we enter a large cylindrical volume, the containment vessel, with the reactor in the center of the room. The walls and ceiling are a smooth, white, continuous surface, the inner face of what I'm told is a 4 foot-thick concrete and lead wall. A perfect circle, approximately 10' in diameter is punched out of the floor, revealing three feet of concrete and steel. The void's match is lying on the other side of me, lifted from its position my a X-ton crane built into the ceiling. The reactor is temporarily shut down for maintenance, so this removal is a rare glimpse into underworkings of the reactor, which for all intents and purposes, seems to just be more pipes. We move towards the center of the room. A radial array of cylindrical spokes protrude out to eight small working stations around the reactor. Each station is marked by a series of lights and switches, the highlight of which is a small portal that allows radiation particles to escape the reactor and collide with experimental matter. We continue to circumnavigate the reactor in the center, traveling up yellow metal stairs to look into the top and back downstairs into the control room. A series of ticking and scratching dials and meters are moving, documenting movement and volts on scrolls of paper within the wall. Surveillance monitors and a plethora of switches and dials line an entire wall. Behind the observation station is a wall tacked with CAD drawings of every detail of the working reactor. Andrew tells me that in a few week boot-camp regiment of reactor work, the freshman students must memorize and draw every component of the reactor. We stare in amazement before heading back towards the portal through which we entered. Exiting the reactor area involves hovering shoes over a Geigger counter and placing hands inside another reader of some sort which resembles an agricultural scale with a mysterious white box that you must blindly place your hands into before exiting. Everything checks out, no reading on either machine and the meter I was wearing on my person reads the same as when I entered, no exposure.

Nuclear Protest:

1.



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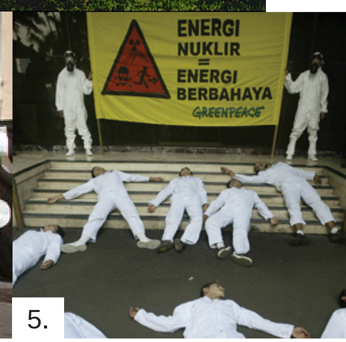

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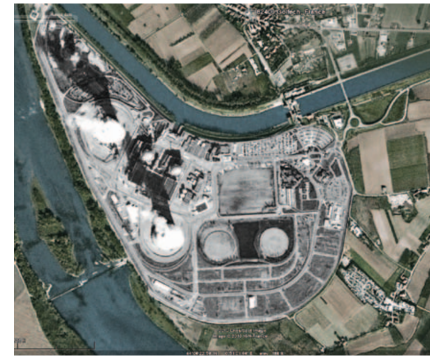
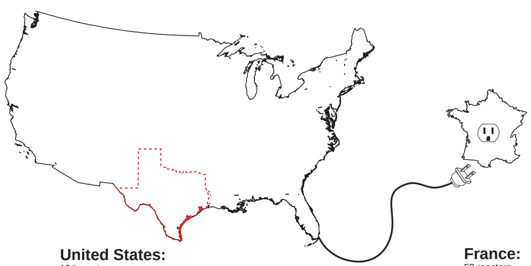
1. http://www.atomicarchive.com/History/hbomb/images/protest.jpg 2. http://www.salem-news.com/stimg/may182009/nuclear-power-pl.jpg 3. http://cache4.asset-cache.net/xc/57415656.jpg?v=1&c=IWSAsset&k=2&d=77BFBA49EF878921F7C3FC3F69D929FD3D6E8E24F8AD364C6EF108C63F522E80FE24D030FFB340E50B6AE4F903F69820 4. http://knowledge.allianz.com/nopi_downloads/images/italy_nuclear_protest_z.jpg 5. http://www.energytribune.com/live_images/AP0704020502.gif 6. http://www.greenpeace.org/raw/image_full/australia/admin/image-library2/greenpeace-protest-against-nuc.jpg

France:
Nuclear Region Precedents



maps and diagrams by author



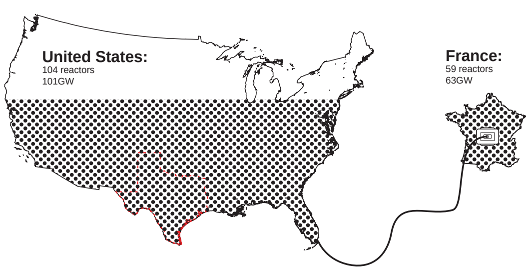


image source: Google Earth

References:

Adee, Sally and Erico Guizzo. “Nuclear Reactor Renaissance.” *IEEE Spectrum Magazine*. August: 2010.

Ascher, Kate. *The Works: Anatomy of a City*. New York: 2005.

Åman, Anders. *Architecture and ideology in Eastern Europe during the Stalin era :an aspect of Cold War history.* New York : c1992.

“A Reasonable Bet on Nuclear Power,” *The New York Times*. February 18, 2010. http://www.nytimes.com/2010/02/18/opinion/18thur2.html?emc=eta1&pagewanted=print

Banham, Reyner. A Concrete Atlantis. Cambridge, MA: 1986.

Barrie, David. *Power To Change: Architecture for a New Age of Nuclear Waste and Decommissioning*. Britain: 1995.

Beckerley, James G. and Joseph M. Harrer, ed. *Nuclear Power Reactor Instrumentation Systems Handbook*. Prepared for the Division of Reactor Development and Technology, U.S. Atomic Energy Commission.

Chirkov, I.V. *Nuclear Power Engineering and Thorium Resources*. pp. 647-654. New York: 1971.

Cravens, Gwyneth. *Power to Save the World: The Truth About Nuclear Energy*. New York, 2007.

Down, C. G. *Environmental Impact of Mining*. London: 1977.

Dresser, Peter D. *Nuclear Power Plants Worldwide*. Detroit: 1993.

Deutch, John et al. “The Future of Nuclear Power: an Interdisciplinary MIT Study.”Cambridge, MA: 2003.

Deutch, John et al. “Update of the MIT 2003 Future of Nuclear Power: an Interdisciplinary MIT Study.” Cambridge, MA: 2009.

Eiser, J. Richard. *Nuclear Neighbourhoods: Community Responses to Reactor Siting*. Exeter: 1995.

Follery, Milo D. *Conference on Design for the Nuclear Age*. Washington D.C: 1962.

“Food irradiation,” *Wikipedia*. http://en.wikipedia.org/wiki/Food_irradiation August, 2010.

Gonzaled, Norma L. *High Level Radioactive Waste and Spent Nuclear Fuel Disposal: an Assessment of Impact Evaluations and Decisionmaking Systems*. Austin: 1987.

Hecht, Gabrielle. *The Radiance of France: Nuclear Power and National Identity after World War II*. Cambridge: 1998.

Martin, Richard. “Uranium Is So Last Century — Enter Thorium, the New Green Nuke,” *Wired Magazine*. December 21, 2009.

“Molten Salt Reactor,” *Wikipedia*. http://en.wikipedia.org/wiki/Molten_salt_reactor , July: 2010.

Newberry Library. Military Architecture, Cartography, & the Representation of the Early Modern European City. Chicago: 1991.

New York (N.Y.) Dept. of City Planning. *Zoning handbook: Department of City Planning*. New York: 2006.

NPR. “Visualizing the Electric Grid.” www.npr.org/templates/stpry/story/story.php?storyId=110997398. May: 2009.

“Nuclear Medicine,” *Wikipedia*. http://en.wikipedia.org/wiki/Nuclear_medicine , August: 2010.

“Nuclear Power,” *Wikipedia*. http://en.wikipedia.org/wiki/Nuclear_power, October, 2009.

Openshaw, Stan. *Nuclear Power: Siting and Safety*. Boston: 1986.

Parent, Claude. *Les Maisons De L’Atome*. Paris: 1963.

“PowerNow! Small, Clean Plants.” New York State. http://www.nypa.gov/facilities/powernow.htm , June, 2010.

Rose, Judah L. *Nuclear Energy Facilities and Public Conflict: Three Case Studies*. Washington D.C: 1979.

Sorensen, Kirk. “(Utility-Scale) Submarine Power Plants.” http://energyfromthorium.com/2006/06/19/utility-scale-submarine-power-plants/ June 19th, 2006.

Sorensen, Kirk. “Lessons for the Liquid-Fluoride Thorium Reactor(from history).” http://home.engineering.iastate.edu/~pjscott/Sorensen_Google_LFTR.pdf Presentation, Mountain View, California. July 20, 2009.

Schewe, Phillip F. *The Grid: A Journey through the heart of our electrified world*. Washington D.C: 2007.

Sweet, Colin, *A study of Nuclear Power in France*. Polytechnic of the South Bank Dept of Sciences. London, March 1981.

Thorium: http://www.world-nuclear.org/info/inf62.html October, 2009.

“Timeline of the Nuclear Age.” http://atomicarchive.com/Timeline/Time1900.shtml

Trocki, Tammy, et. al. *Strategic Plan Fiscal Years 2008-2013*. United States Regulatory Commission. NUREG-1614, Vol. 4. 2008.

United States Department of Defense. *Nuclear Posture Review Report*. April, 2010.

References (continued):

U.S. Department of Energy Office of Environmental Management. *Closing the Circle on the Splitting of the Atom: The Environmental Legacy of Nuclear Weapons Production in the United States and What the Department of Energy is Doing About it*. Washington D.C: 1996

Virilio, Paul. *Bunker archéologie*. Paris: 1976.

Wald, Matthew L. “In a Bid to Revive Nuclear Power, U.S. is Backing New Reactors,” *The New York Times*. February 17, 2010.

Walter, David. “Towards a Thorium Economy: Draft Perspective.” http://www.dailykos.com/story/2009/1/5/153348/5912/954/680446 , January, 2009.

Winter, John V. *Power Plant Siting*. New York: 1978.